AUTOMOBILE ENGINEER

DESIGN · PRODUCTION · MATERIALS

Vol. 42 No. 554. JUNE, 1952 PRICE: 3s. 6d.

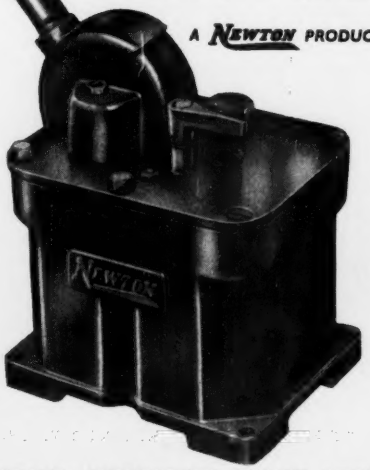
POWER

by

POWER JACKS

★HYDRAULIC PUMPS
of proved efficiency
for hand or power operation

A NEWTON PRODUCT



TECHNICAL DATA

Normal operative pressure	1,500 lbs. sq. in.
Maximum operative pressure (Blow Off)	2,500 lbs. sq. in. (or to specification)
Output complete stroke	·825 cu. ins.
Effective piston area	·600 ins.
Handle leverage ratio	16 – 1
Alternative fluid capacities in pints	2¼ pts., 6 pts., 16 pts., 24 pts., 32 pts.

Larger capacities to special order.
Vertical or horizontal pump handle.

JACKS from 1 TON to 5 TONS
in a variety of stroke lengths

★ *Full information, price, etc., will be sent on request*

POWER JACKS LIMITED
VALETTA RD · ACTON · LONDON · W3

TELEPHONE: SHEPHERDS BUSH 3443 (4 Lines) TELEGRAMS: NEWSORBER, EALUX, LONDON

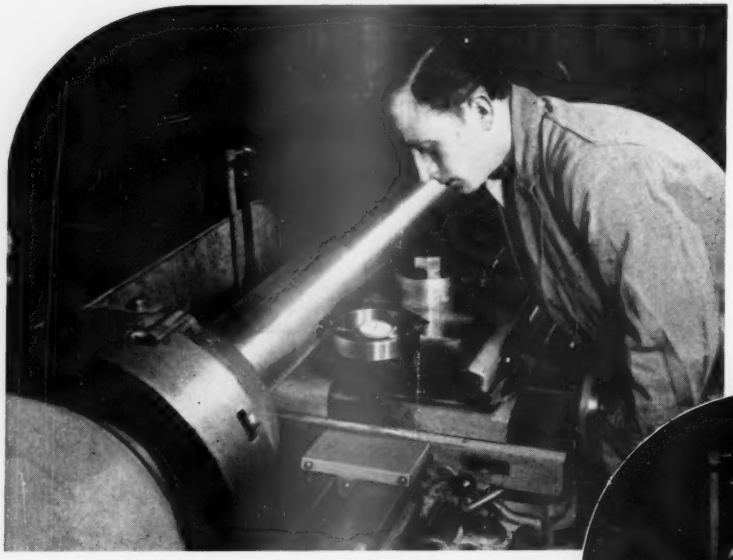
ESC

Investigate

TURNING TOOL PROBLEMS

WITH HIGH SPEED STEEL AND TUNGSTEN CARBIDE

as part of their continuous research and study of metal cutting technique



- ★ TOOL PERFORMANCE
- ★ CHIP FORMATION
- ★ CUTTING FLUIDS
- ★ SURFACE FINISH
- ★ RATE OF METAL REMOVAL

The above photographs, taken in the ESC Cutting Tool Development Department, show an engineer checking just two of the many variables—cutting speed and hardness of the test bar, during a turning tool investigation.

Makers of high quality Engineers' Cutting Tools for over a century

ENGLISH STEEL CORPORATION LTD

OPENSHAW MANCHESTER

Who wants higher output?

Well everyone, of course. And many are getting it. The metal-working industries are becoming increasingly automatic-minded . . . one reason why so many producers of turned parts are thinking in terms of Wickman Automatics—the Coventry-built multi-spindle machines with the exclusive no-cam changing feature.

More and more of these fast producers are helping to raise output in Britain's major industries, supported by a comprehensive tooling and engineering service.

A full range of these machines will be demonstrated at the International Machine Tool Exhibition, Olympia.

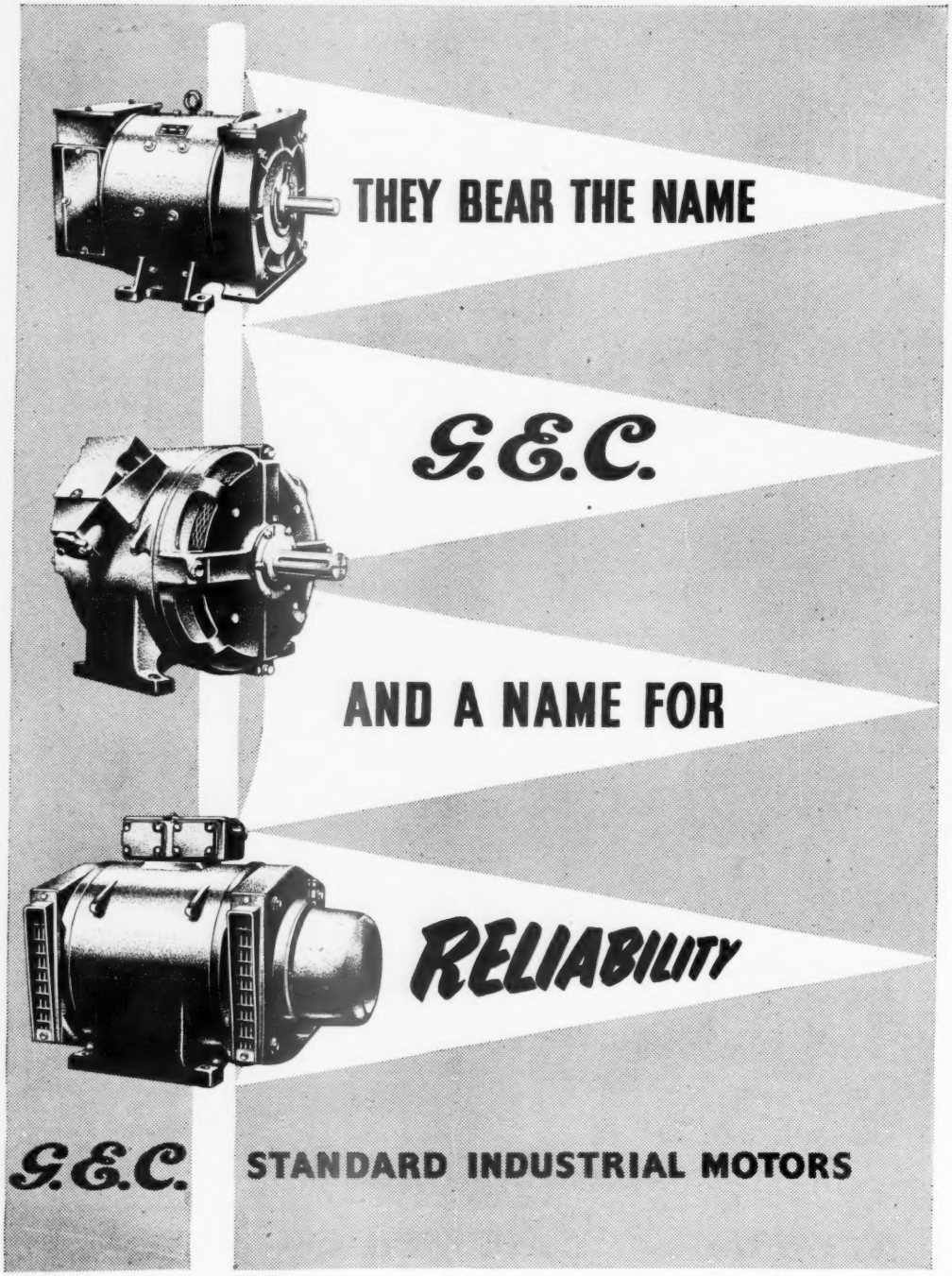
Wickman 6" Five Spindle Chucking Automatic.

WICKMAN *of* **COVENTRY**

LONDON · BRISTOL · BIRMINGHAM · MANCHESTER
LEEDS · GLASGOW · NEWCASTLE · BELFAST

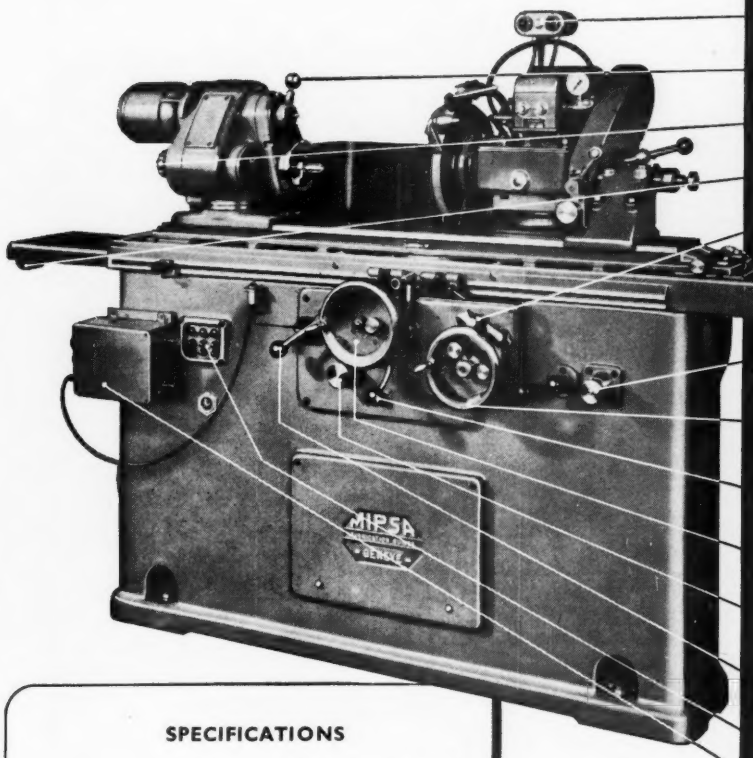
Wickman

254 WM.



THE GENERAL ELECTRIC CO. LTD. MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

MIPSA HIGH PRECISION
UNIVERSAL GRINDING MACHINES



ETAMIC SIZING INDICATOR

WORK-SPINDLE DRIVE ENGAGEMENT LEVER

INFINITELY VARIABLE SPEED CONTROL

INFINITELY VARIABLE DWELL CONTROL

AUTOMATIC INCREMENTAL FEED ADJUSTMENT TO GRINDING HEAD

INFINITELY VARIABLE HYDRAULIC FEED TO GRINDING HEAD

MANUAL FEED TO GRINDING HEAD (COARSE)

MANUAL TABLE MOVEMENT ENGAGEMENT LEVER

MANUAL TABLE MOVEMENT—TWO SPEEDS

INFINITELY VARIABLE HYDRAULIC TRAVERSE CONTROL VALVE

AUTOMATIC PLUNGE FEED AND TRAVERSE LEVER

MAIN SWITCH PANEL

ETAMIC AUTOMATIC SIZING CONTROL

SPECIFICATIONS

		Type U 120/400	Type U 130/750
Height of centres	mm.	120	130
Maximum distance between centres	mm.	400	750
Maximum diameter	mm.	220	240
Maximum longitudinal traverse of table	mm.	410	800
Minimum automatic feed of grinding wheel	mm.	0.0025	0.0025
Minimum speed of grinding wheel	r.p.m.	2,000	2,000
Maximum speed of grinding wheel	r.p.m.	4,000	4,000
Speeds of internal grinding device (same for both type)	r.p.m.	12,000—14,500—17,500—23,000	
Workpiece speeds infinitely variable from...	r.p.m.	120 to 580	
Table speeds ... ...m./min.		0.10-7	

Work-table and grinding wheel-head can be swivelled.
Work-head can be turned through 90°.
Grinding wheel-head has quick return motion (hydraulic).
Micrometer depth adjustment is provided on slow feed.
Table guides are pressure lubricated.

INTERNATIONAL MACHINE TOOL EXHIBITION LONDON 1952 OLYMPIA SEPT 17-OCT 4

WICKMAN *of* COVENTRY

LONDON · BRISTOL · BIRMINGHAM · MANCHESTER
LEEDS · GLASGOW · NEWCASTLE · BELFAST

Wickman

242 F77

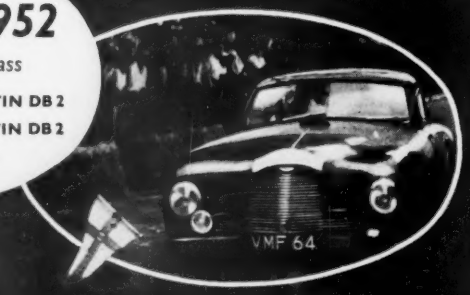
Mille Miglia 1952

Over 2 Litre Touring Car Class

1st. — T. WISDOM — ASTON MARTIN DB 2

2nd — R. PARNELL — ASTON MARTIN DB 2

(Subject to Official Confirmation)



The Aston Martin DB 2 (VMF 64) repeats its outstanding success of last year by again winning its class in the Mille Miglia.

This car was successful in the Le Mans 1950, Mille Miglia 1951, Le Mans 1951 and Alpine Rally 1951. For all these events it was fitted with Mintex Brake Liners.

When high performance counts — you can rely on

MINTEX

MINTEX BRAKE & CLUTCH LINERS are manufactured by BRITISH BELTING & ASBESTOS LTD., CLECKHEATON, YORKSHIRE, and are obtainable from all Mintex Service Depots and Stockists.

F. & B. Brown Tools Ltd.
SPEEDICUT WORKS CARLISLE STREET EAST SHEFFIELD
ENGINEERS' CUTTING TOOLS OF ALL TYPES
FBT
FASTER & BETTER TOOLS
FIRST & BEST

FULLER HORSEY

SONS & CASSELL

Wish to advise their clients that owing to erection of the new Lloyd's Building in Billiter Square, it has been necessary to remove to the new offices

AT

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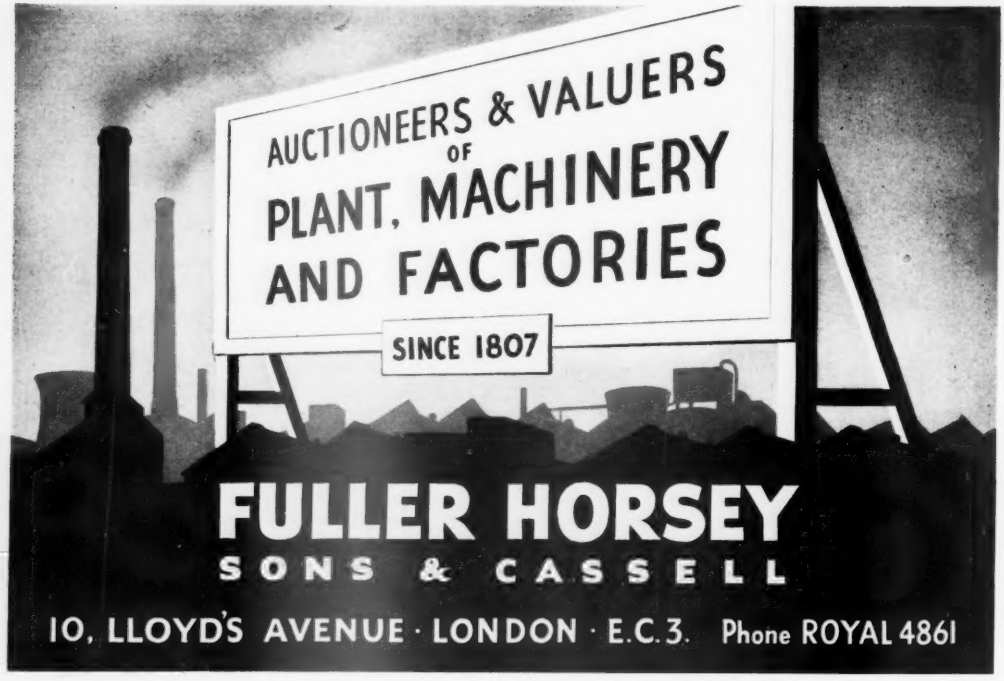
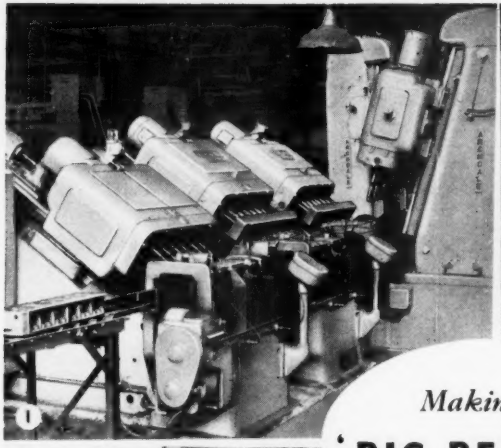
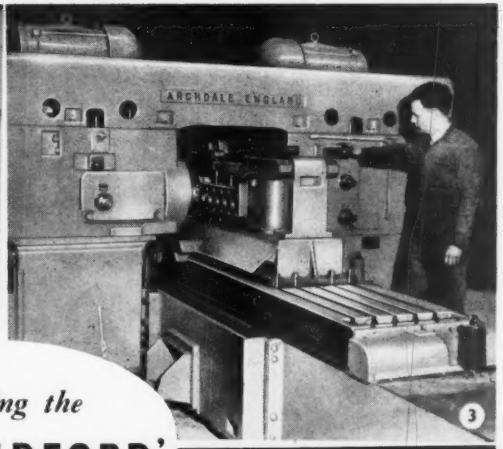
Telephone ROYAL 4861



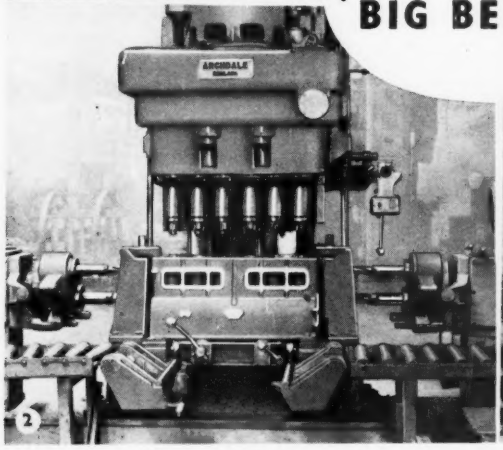
Rathbone

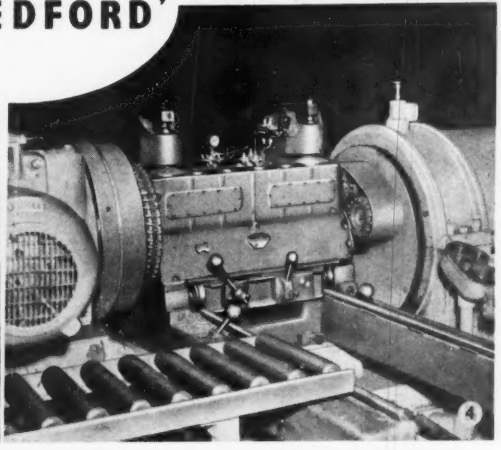




Making the

'BIG BEDFORD'





1. One of two automatic transfer machines for machining cylinder heads. These two machines perform all operations: valve guide holes and throats (leaving for fine boring), and the drilling, facing and tapping of spark plug holes, etc. Work is indexed automatically from station to station: the operator simply loads and unloads.

2. Six-spindle vertical borer or rough boring Cylinder bores. There are also two independent horizontal drilling heads with two spindles for core drilling plug holes and camshafc bores.

3. Special horizontal duplex miller for machining the cylinder head joint face and the sump joint face. There are two cutters on one head for roughing and semi-finishing the cylinder head joint face and three on the other for roughing and finishing the sump joint face. Each head is driven by its own 40 h.p. motor. Feed rates are variable between 20 and 60 in. per minute. A 0.125 in. roughing cut is taken.

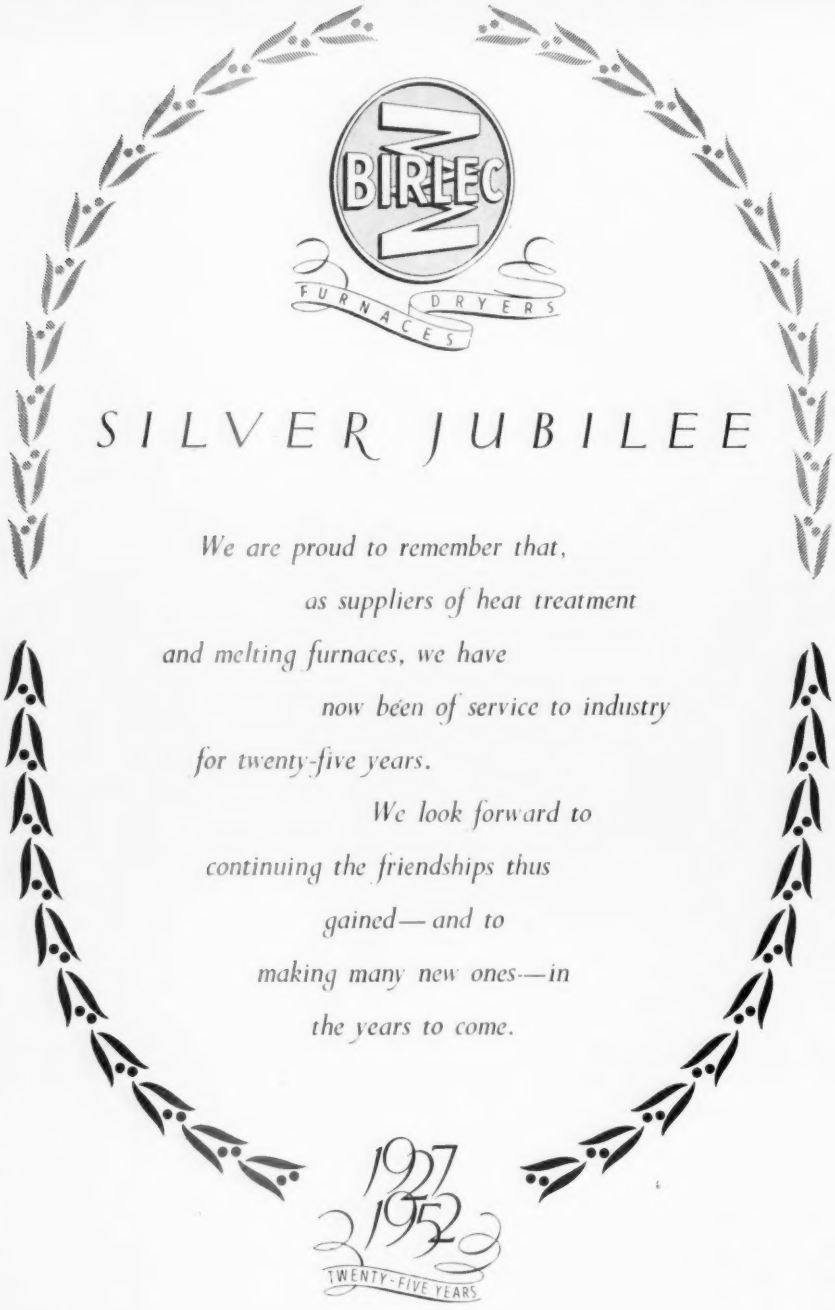
4. Combined duplex milling machine. One head carries a 18½ in. dia. cutter with 50 teeth for finish milling the front and face of the cylinder block. At the other end is a planetary 2-spindle milling head for rough and finish milling the rear face.

ARCHDALE *SPECIALS*

for high production in the automobile industry

JAMES ARCHDALE & CO. LTD., LEDSAM STREET, BIRMINGHAM, ENGLAND

SOLE SELLING AGENTS: ALFRED HERBERT LTD., COVENTRY & BRANCHES



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GRACE

BORG & BECK

UTILITY

SERVO PROBLEMS THAT ARE SOLVED BY LOCKHEED

The de Havilland

'COMET'

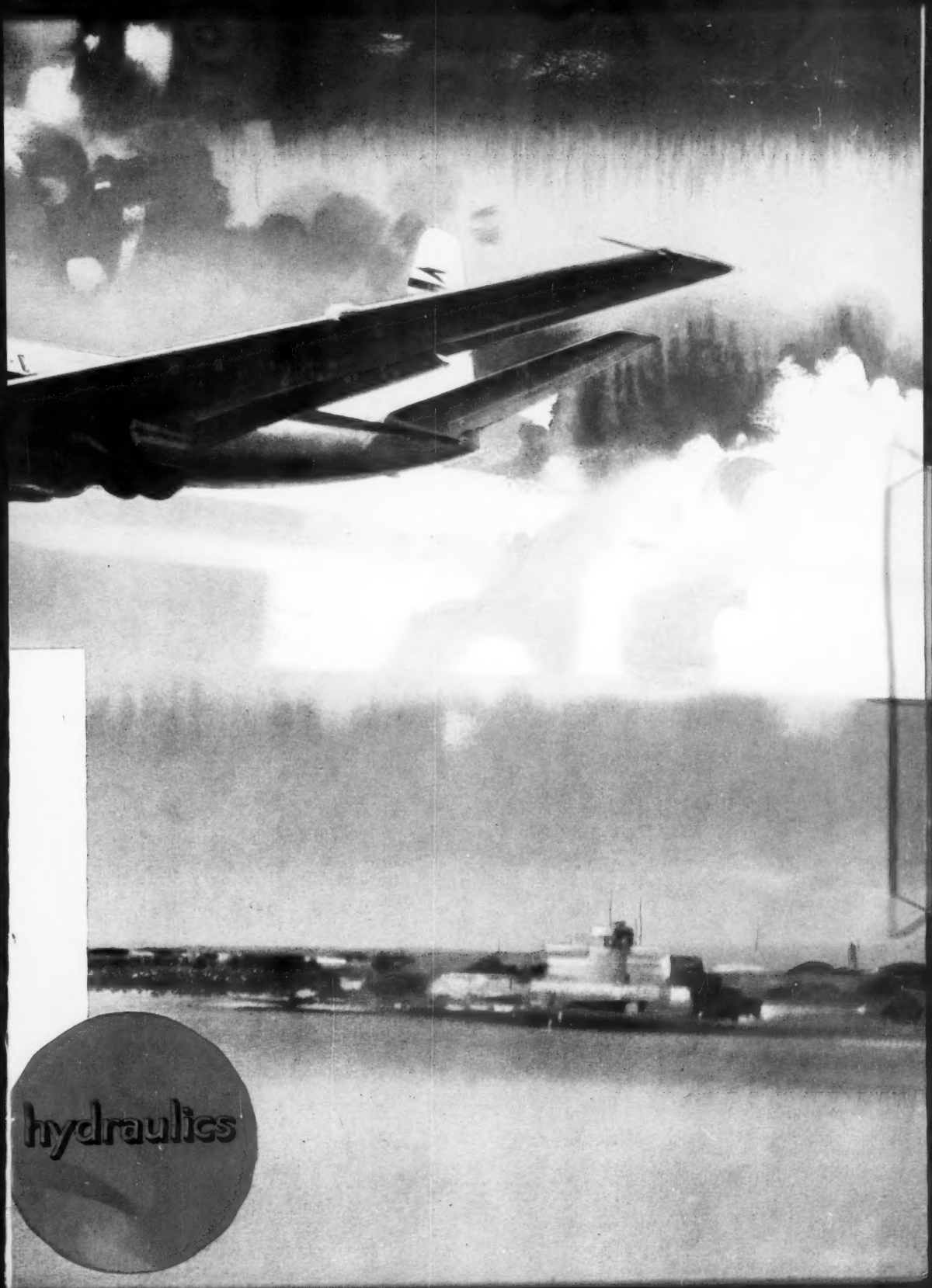
Although as a reader of the 'A.E.' your first thought of Lockheed is in connection with brakes, nevertheless Lockheed development has been progressing for many years in other fields. Our faith in hydraulics was such that we set up different departments to deal with different problems, and in fact, their practice sometimes differs appropriately to suit the individual requirements. Here is a famous aircraft whose controls are assisted, proportionately to the manual effort of the pilot, by the Lockheed 'Servodyne' system.

The Lockheed hydraulic pump developed for aircraft, as used in this system, is so efficient and robust that a similar type is employed in the Lockheed servo system for heavy road vehicles.

AUTOMOTIVE PRODUCTS COMPANY LTD., LEAMINGTON SPA.

ALL-BRITISH Lockheed

REGD. TRADE MARK


hydraulics

ENGINE

DURABILITY
is cheap to buy

Abrasive dirt is universal, and the most effective way of using its destructive nature to lap down all the important wearing surfaces of the engine is to pump it round with the oil!

The alternative is to arrest it with the most effective filter to be obtained—one that will capture the insidious micronic-sized particles that do the most damage.

We claim that the Purolator is in fact the most effective filter available and that the cost is fractional compared with the benefits it brings.

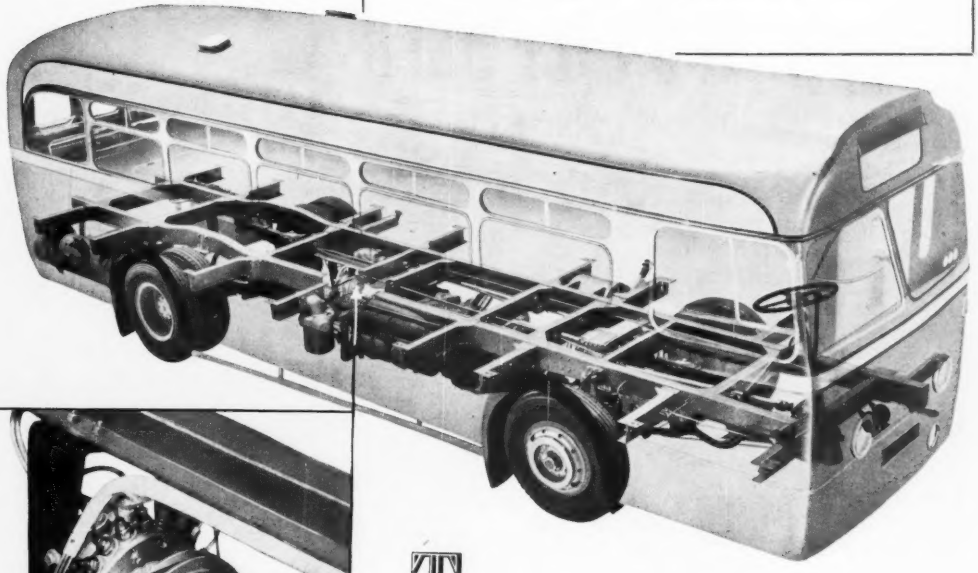
AUTOMOTIVE PRODUCTS COMPANY LTD. LEAMINGTON SPA

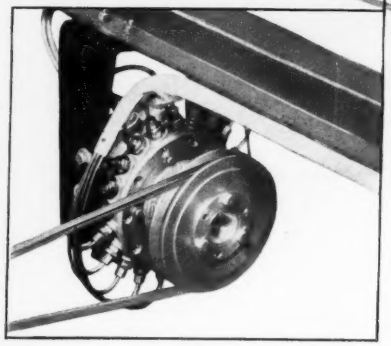
PUROLATOR
REGD. TRADE MARK

MICRONIC OIL FILTER

the 'Inside story' of the *Syndromic*

AUTOMATIC MILEAGE CONTROLLED CHASSIS LUBRICATOR





THIS X-ray photograph of a coach is in itself unusual but the really interesting feature is the " Syndromic " chassis lubricator with which it is fitted.

This lubricator gives a predetermined and measured ' shot ' of oil to each individual bearing every mile, operating efficiently and automatically all the time the vehicle is running. Once fitted and regulated it requires no attention other than keeping the tank replenished with oil.

Now see the advantages . . . no ' dead ' time for periodical lubrication—more pay loads . . . wear practically eliminated on spring shackles, king pins, steering swivels, etc.—no replacement costs.

Why not fit your vehicle with " Syndromic " automatic mileage controlled chassis lubrication ?

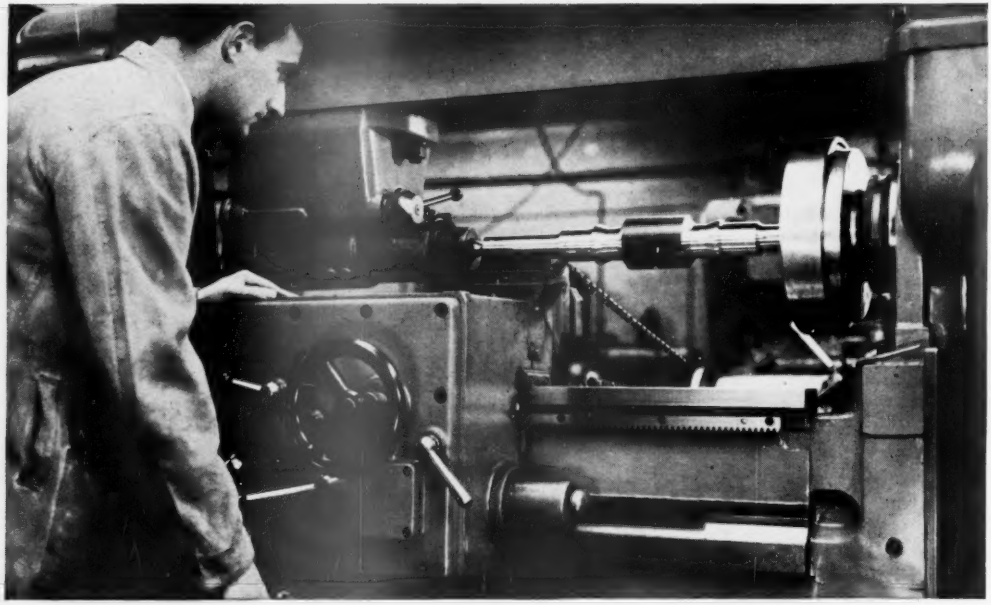
Let us send you full particulars of the system.

TECALEMIT
The Authority on Lubrication
PLYMOUTH & BRENTFORD

T 378

no stone is left unturned

The illustration shows one of a number of Fischer hydraulic copying lathes which we use for turning worm shafts.



See us at the
MECHANICAL HANDLING EXHIBITION
STAND E 12

If you want a thing done well, do it yourself is the motto that hangs above the Holroyd bed. And though we live up to this ideal in the larger part of our worm gear manufacture, there are some operations for which we have to use machines other than those we make ourselves.

Where do we get these machines ? We take trouble examining this one and that. We prowl around looking for the best that money can buy and only when every metaphorical stone is lying bottoms up do we make our choice.

The result is Holroyd Worm Gears. Worth it, don't you agree?

Holroyd ***WORM GEARS***

JOHN HOLROYD & CO. LIMITED • MILNROW • LANCASHIRE

CRC 152

When you want quick friendly *personal service ..

Bolts, Nuts, Rivets, Screws, Studs & Washers in all metals and threads • Pressure Gauges Reducing and Relief Valves Steam Traps, Cocks and Valves for every service • Ground Flat Stock • Lifting Tackle, Ball & Roller Bearings, Transmission Equipment • Machine Tools • Ferrous & Non-Ferrous Tubes and Fittings • Pumps • Plumbers Brassfoundry.

WE ARE ALSO EXPERTS IN NON-STANDARD SPECIFICATIONS AND SHALL BE PLEASED TO RECEIVE YOUR ENQUIRIES.

ring up **Walkers!**

* *Personal service means that your call is handled immediately by someone who can not only take all your instructions, but is ready and technically able to offer practical, helpful advice.*

M. W. WALKER AND STAFF LTD.

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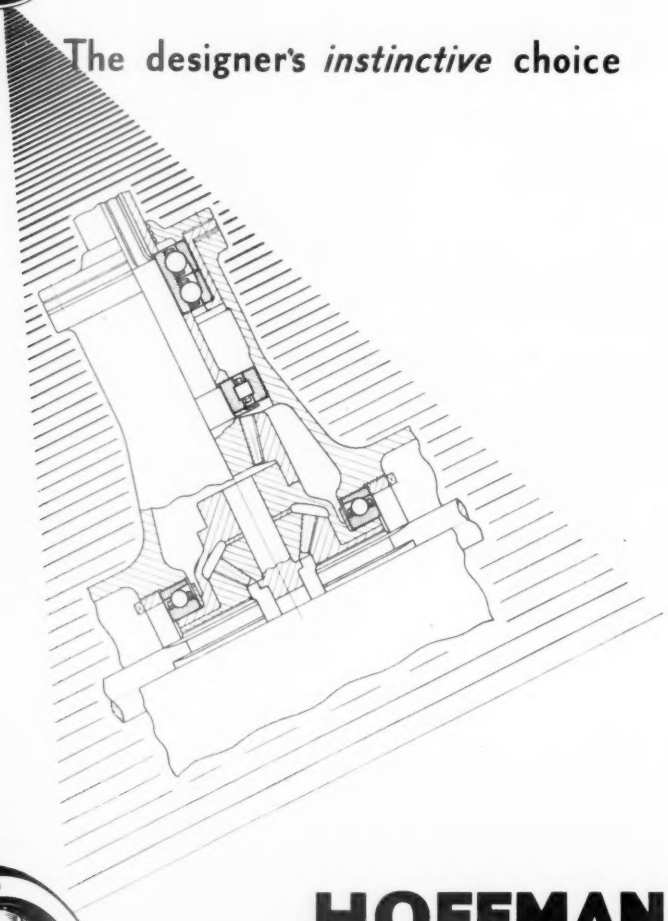
● REAR AXLE BEARINGS ● REAR AXLE BEARINGS ● REAR AXLE BEARINGS ● REAR AXLE BEARINGS

HOFFMANN

The designer's *instinctive* choice

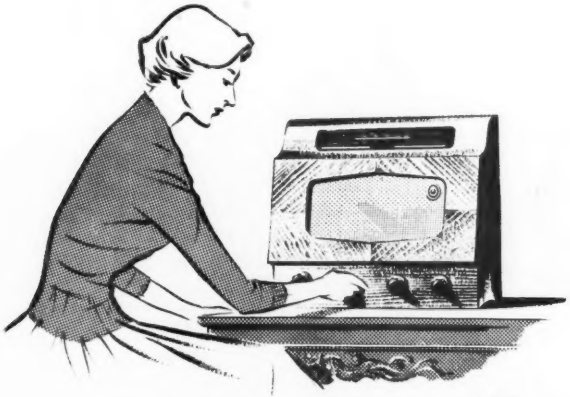


HOFFMANN BEARINGS

Robustness and reliability are essential for the trouble free performance of the back axle bearings. The wearlessness of the Hoffmann Bearings ensures constant accurate gear mesh resulting in long life and quieter running.

THE HOFFMANN MANUFACTURING CO. LTD., CHELMSFORD, ESSEX

● REAR AXLE BEARINGS ● REAR AXLE BEARINGS ● REAR AXLE BEARINGS ● REAR AXLE BEARINGS ● REAR AXLE BEARINGS



Unfinished Symphony

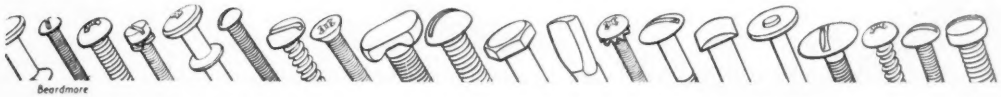
Yes, the "Unfinished" or "Piano Roll Blues", — Toscanini or Fats Waller, — they're all within reach of our hand, thanks to the modern radio set. Just another present-day luxury which we have come to take for granted, and which would have made our grandfathers gasp with amazement. Yet from our point of view a radio set is more than that. It is one of numerous examples of everyday articles which play a very important part in our lives, and which are absolutely dependent upon the products we manufacture.

In this case, not only the symphony would be "unfinished", but also that very nice Murphy A.186 receiver we have illustrated, were it not for the screws which hold together the various components. Incidentally, the Murphy people are just one example of leaders in their particular field who recognise and make extensive use of our specialised services.

Linread LIMITED

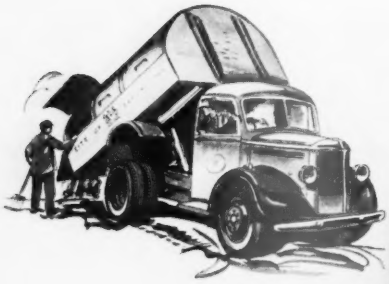
We supply all industries requiring small fasteners of the highest quality to hold together the products they manufacture. Our specialists are always at your service to advise and assist you with your own particular problems.

LINREAD LTD. STERLING WORKS COX ST. BIRMINGHAM 3



Beardmore

Hydraulic efficiency?

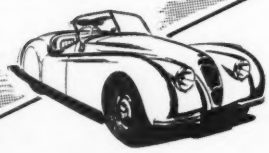


Dunlop Flexible Pipes put an end to pipe difficulties. Consider some of the practical advantages which they offer: durability and high fatigue-resistance, resulting from special Dunlop design and the traditional quality of materials and workmanship; short end-fittings that offer ease of installation; secure end-fittings that cannot be shifted by internal pressure. There are many types of coupling for original fitment or replacement, and, of course, high, medium, and low pressure ranges. The Dunlop Technical and Consultative Service is ready to advise you on all application problems.

IH 906

DUNLOP RUBBER CO. LTD., FOLESHILL, COVENTRY

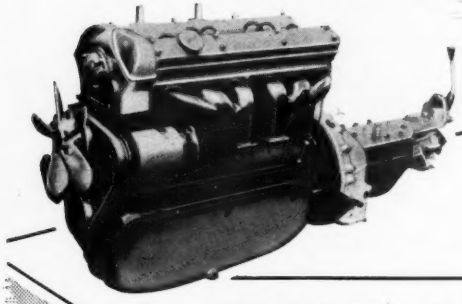
Jaguar Cars Ltd insist on HARPER QUALITY



The exhaust manifolds of the new Jaguar XK120 are enamelled by

HARPERS

This remarkable car, with its world renowned performance, embodies all that is best in British engineering—Harpers are entrusted with the enamelling of the manifolds in a high quality, heat-resisting vitreous enamel.



CASTINGS WITH THE HARPER SKIN

Harper quality covers grey iron and Meehanite castings, and also metal pressings, machining, enamelling and other finishes and sub-assembly work.

JOHN HARPER & CO. LTD. JOHN HARPER (MEEHANITE) LTD.
ALBION WORKS Phone: WILLENHALL 124 (5 lines) Grams: HARPERS WILLENHALL **WILLENHALL**

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RB H282

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TERRY'S"

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You'd have a surprise—**CLIPS** in every possible shape and size, **CLIPS** in steel, bronze, stainless, plated, etc., **CLIPS** for every trade under the sun . . . and if you want a clip made to specification TERRY'S Research Department is there—ready and willing to give you the benefit of 96 years' experience.

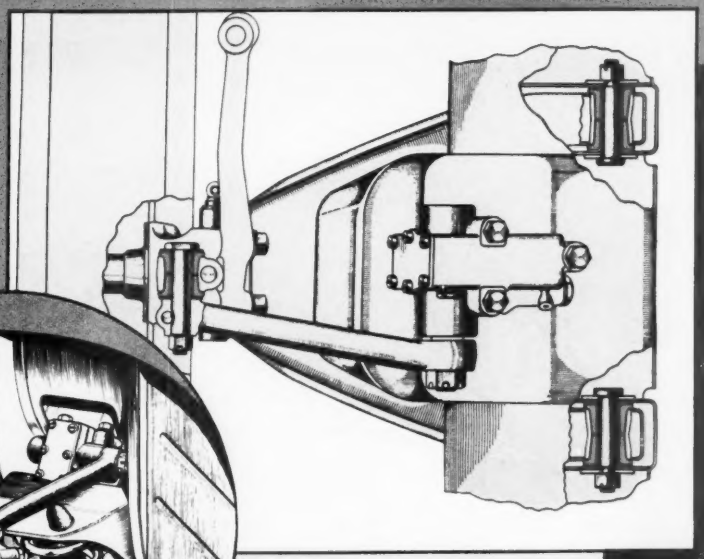
Want to know all about springs?

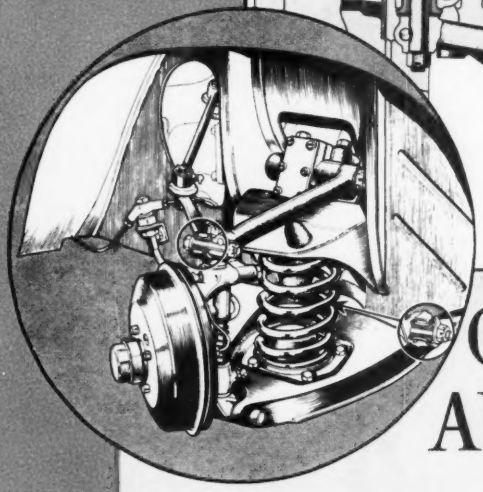
Here's a book packed with spring know-how from cover to cover—the finest of its kind today. Post free 12/6.

. . . and here are three "specials"

Three really popular clips. Nos. 80 and 81 come ½" to 2" from stock. No. 300—an exceptionally good drawing board clip—costs 5/- a dozen (inc. p.t.), from stock.

Sole Makers: **HERBERT TERRY & SONS LTD., REDDITCH** · LONDON · BIRMINGHAM · MANCHESTER





On the new AUSTIN '7'

This interesting new car—like so many of the other Austin models, has Metalastik 'Bonded Cone' bushes on the I.F.S. system.

The illustrations show clearly the effective manner in which these have been applied and the general simplicity of this most interesting layout. Metalastik 'U.D.' bushes are used in the rear suspension.

Metalastik 'Bonded Cone' bushes are also used on the Austin 'Somerset', 'Hereford', 'Atlantic', 'Princess' and 'Sheerline' models and on a great number of other important cars.

Their great capacity for both radial and thrust loads, and the higher duty made possible by the famous Metalastik rubber-to-metal weld, have established them as the ideal bushes for these vital situations.

METALASTIK

METALASTIK LTD., LEICESTER

We don't cast in doubt . . .

at T. I.

We prefer certainty. In the foundry, all sporting chances are out. Before casting our aluminium billets and slabs, every melt is sampled, *and within two minutes we have a complete analysis, showing the exact percentage of all constituents.* Anything wrong we correct then and there—with time to check again by yet another analysis before pouring.

This swift accuracy in testing has been made possible by an electronically controlled spectrographic apparatus called a *Quantometer*. Made for us by Applied Research Laboratories in California, it is the only instrument of the kind in this country. It enables us to send a billet to the extrusion press or a slab to the rolling mill immediately after casting, with absolute certainty that it is to specification.

A reason the more for saying . . .

PUT Aluminium FIRST
AND TI IN FRONT OF IT

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"Abominable Snowmen" my foot—said the M.D. They are merely my Little Horses undergoing one of our usual tests. First they run up to the top of Everest and then they run down again backwards. This we call the *Rarefied Atmosphere Test* (Going and Coming). In other parts of the world my Little Horses are on test in deserts *(Coolth)*, under water *(Humidity)* and in Underground Railway Carriages *(High Pressure)*. Also in Selected Government Departments *(Cutting Red Tape)*.

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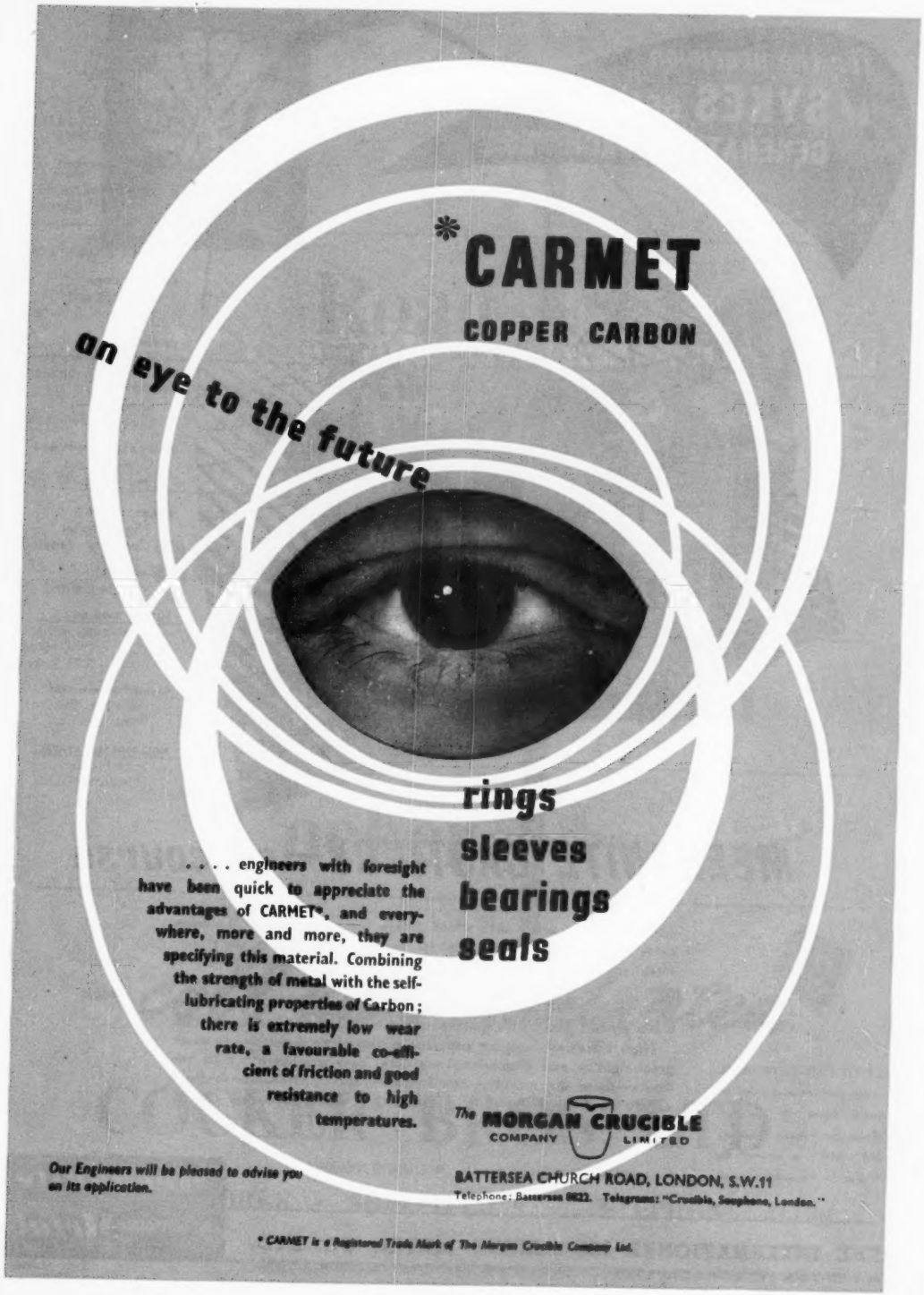
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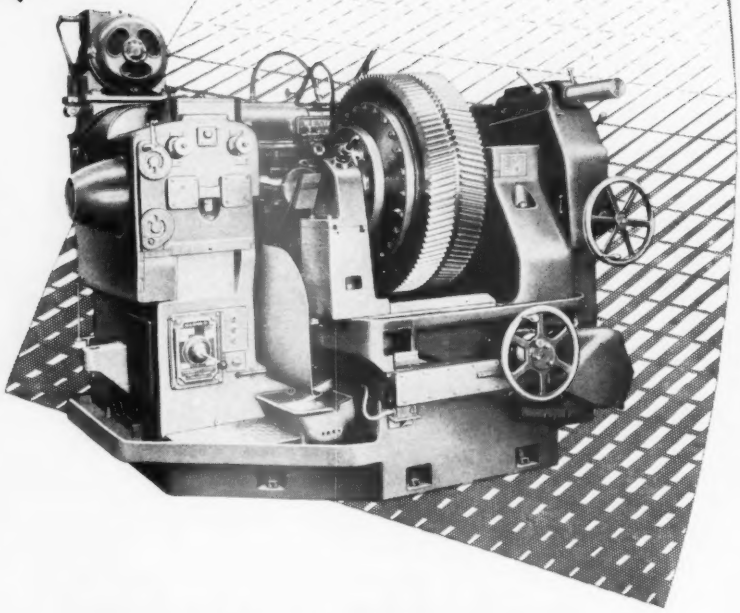

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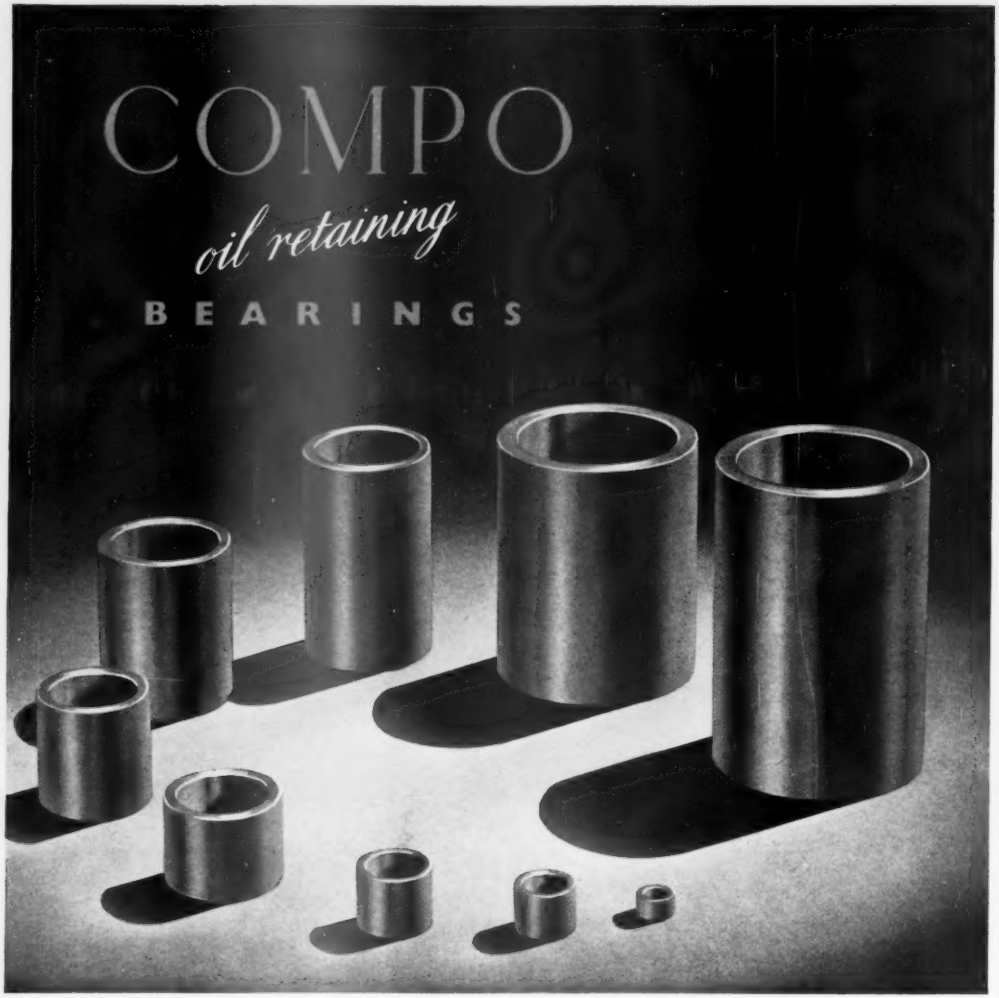

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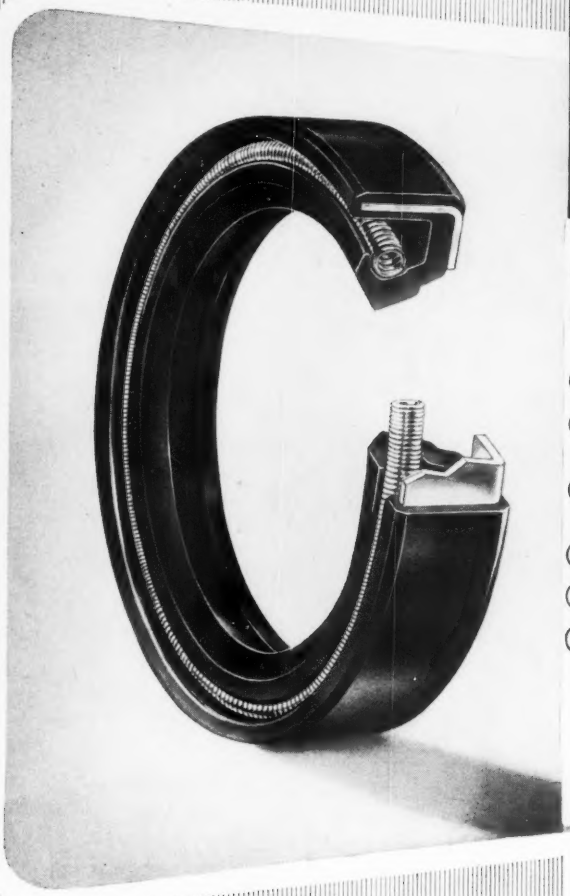

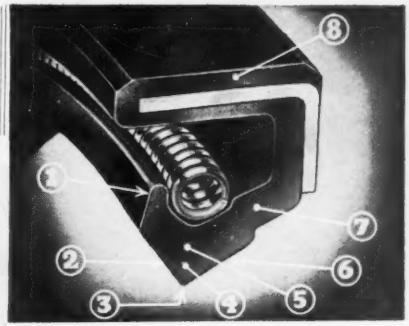

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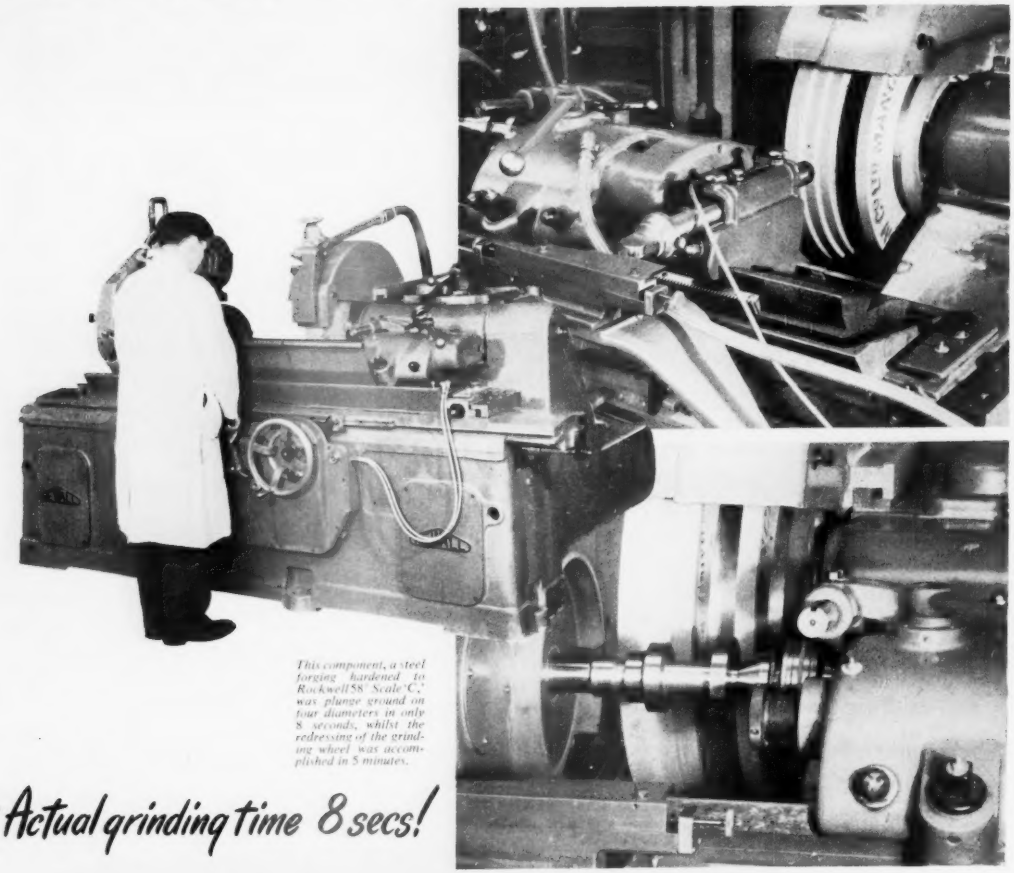

This component, a steel forging hardened to Rockwell 58 Scale 'C', was plunge ground on four diameters in only 8 seconds, whilst the redressing of the grinding wheel was accomplished in 5 minutes.

☆ Actual grinding time 8 secs!

Grind all diameters at one plunge..

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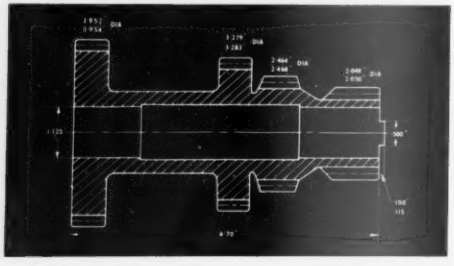

◀ gear transmission countershaft

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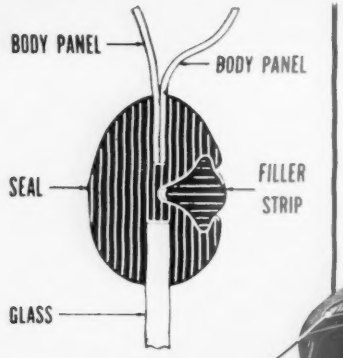

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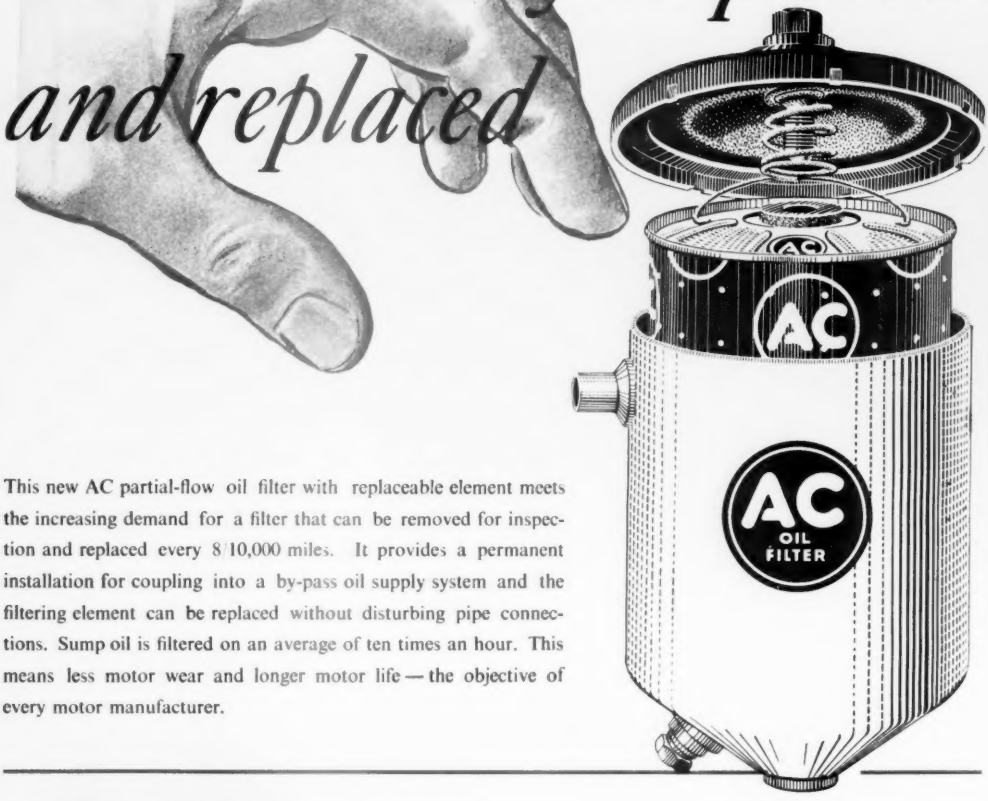
Detachable oil filter

element easily inspected and replaced



This new AC partial-flow oil filter with replaceable element meets the increasing demand for a filter that can be removed for inspection and replaced every 8/10,000 miles. It provides a permanent installation for coupling into a by-pass oil supply system and the filtering element can be replaced without disturbing pipe connections. Sump oil is filtered on an average of ten times an hour. This means less motor wear and longer motor life — the objective of every motor manufacturer.

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from A to Z

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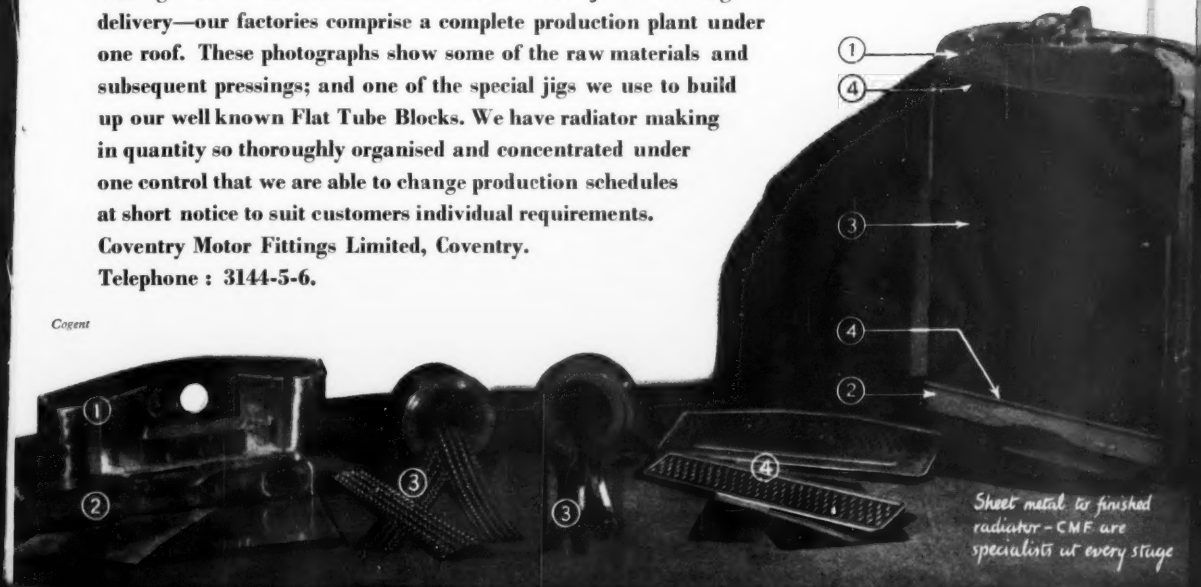

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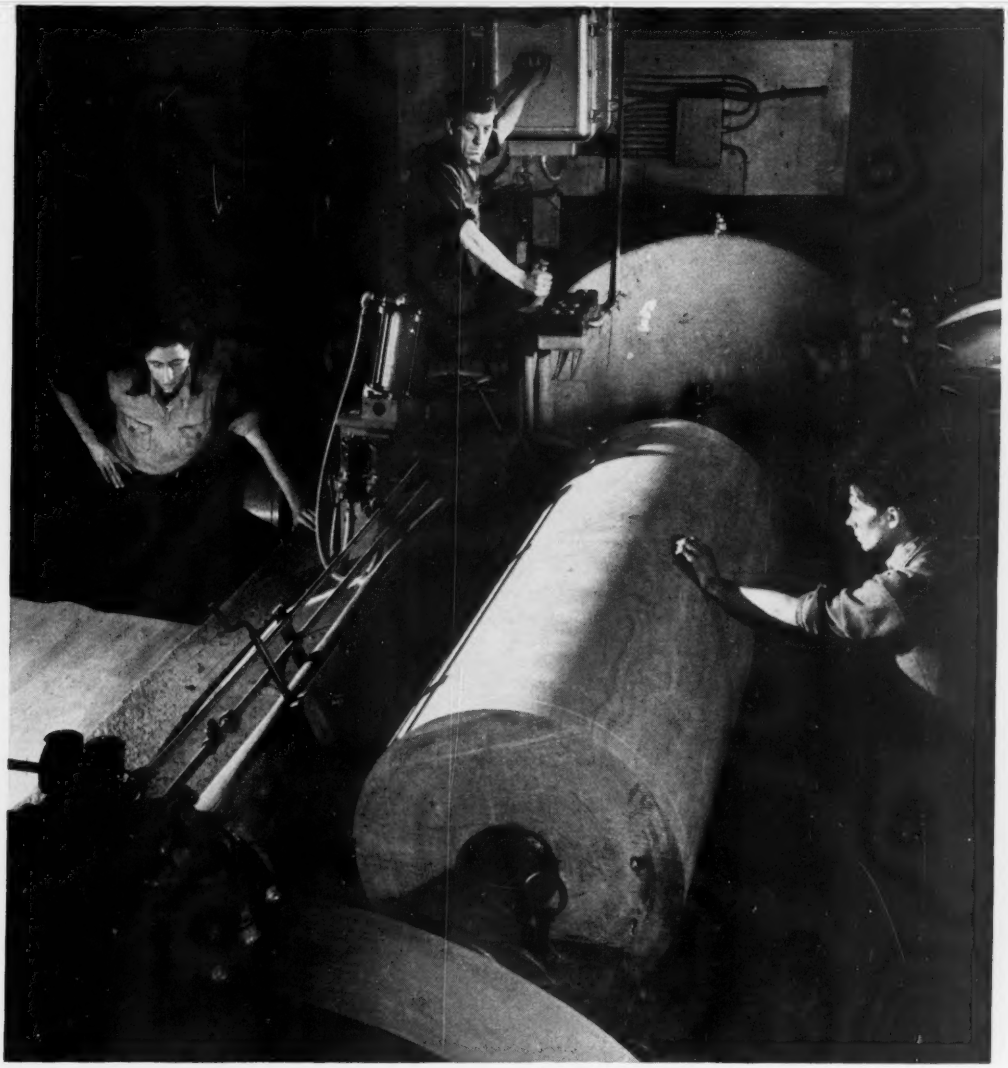

Veneer making by peeling steamed log at Thames Plywood Manufacturers Limited

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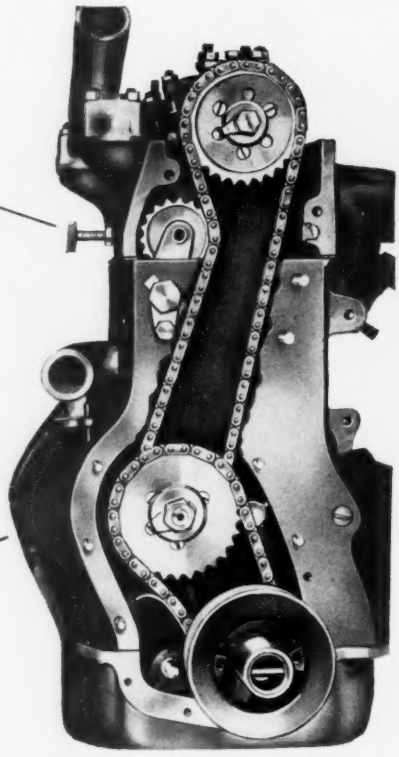

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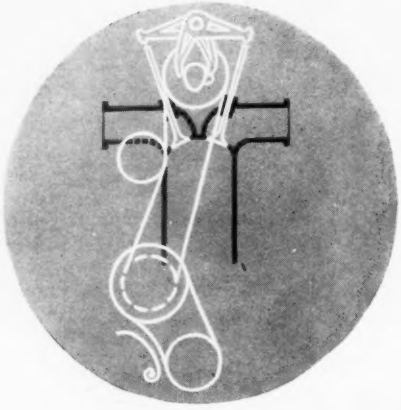

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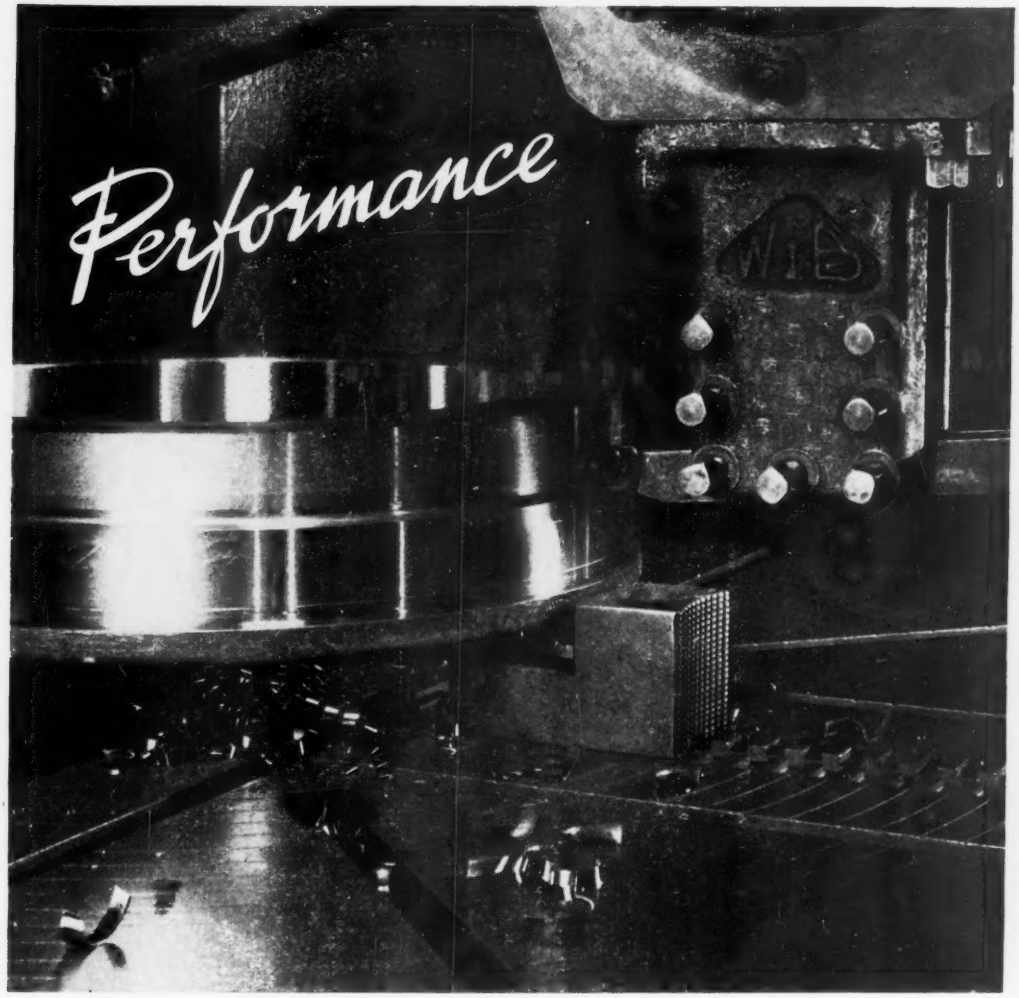

This unretouched photograph shows the heavy, rough machining of a steel tyre. The tool is tipped with Cutanit Grade R which is unequalled for this class of work.

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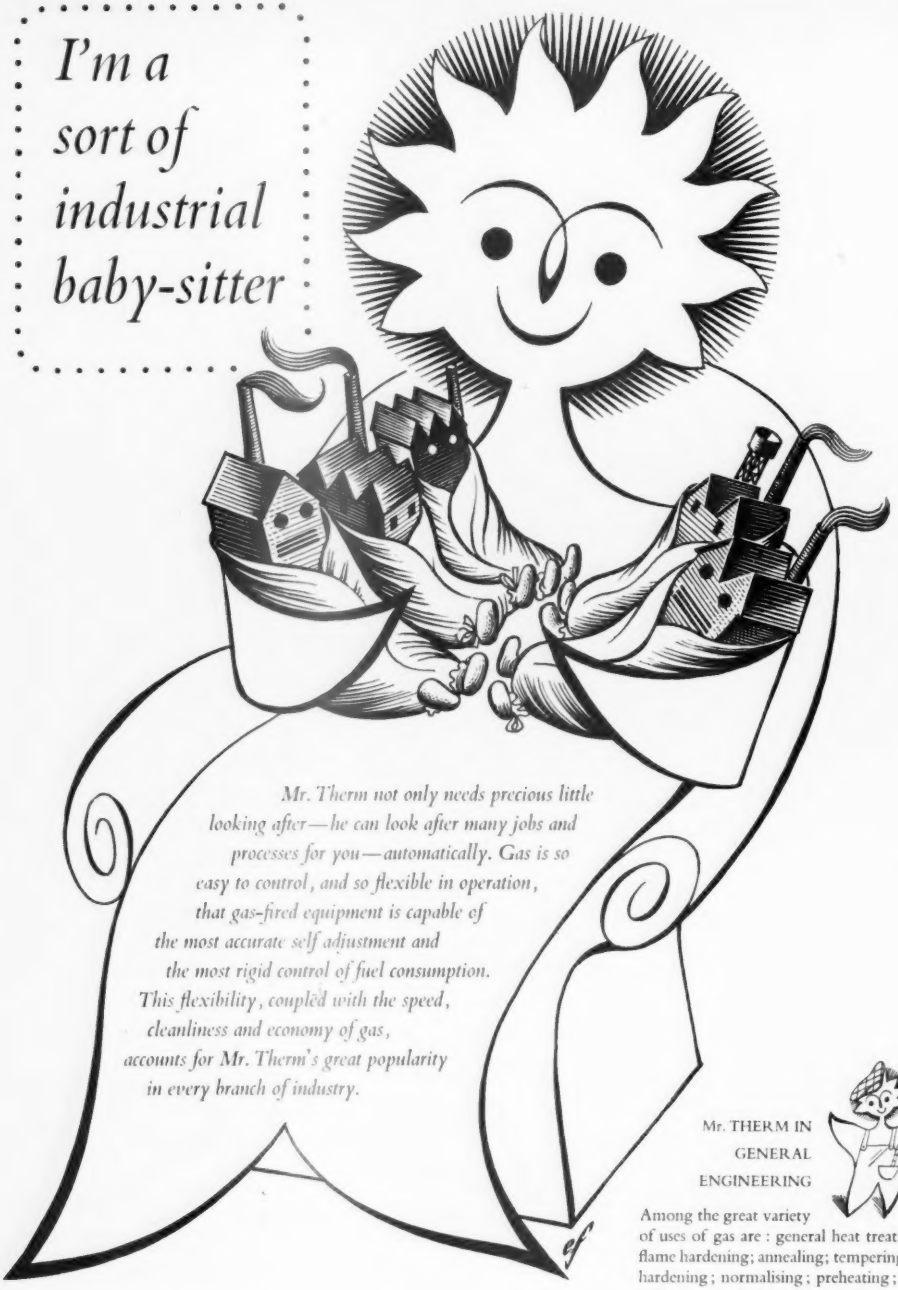

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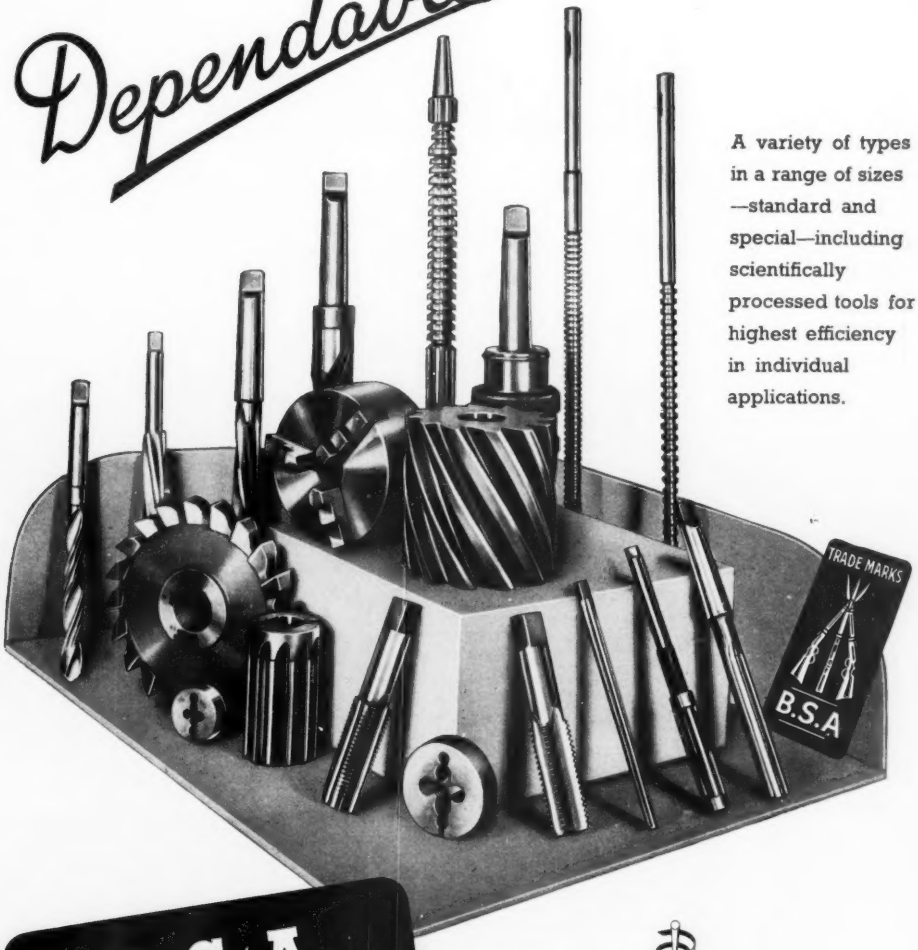

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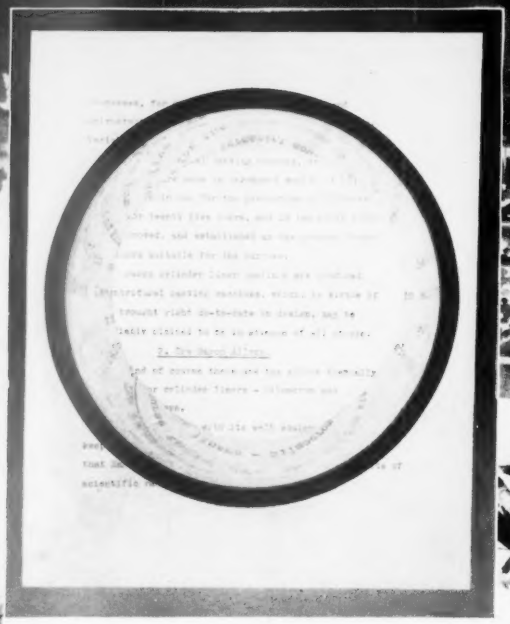

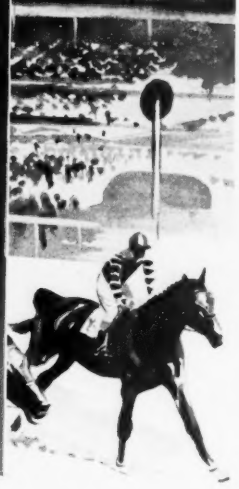

The above photograph of the bore of a HAGCO Liner *after 120,000 miles* graphically shows how the iron has taken such a beautiful "mirror" polish that it reflects perfectly a page of typewriting looked at through the Liner. Conclusive proof to all motor engineers of the infinitesimal wear, and the outstanding resistance to abrasive action, of HAGCO "Silmocrom" and "Austenitic" Cylinder Liners.

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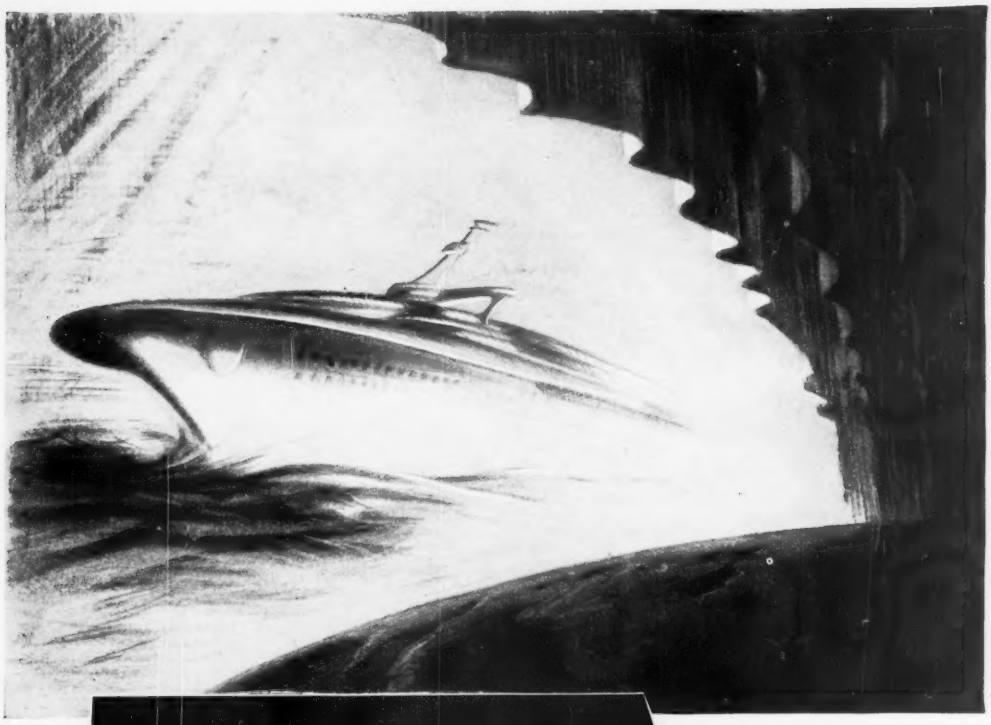

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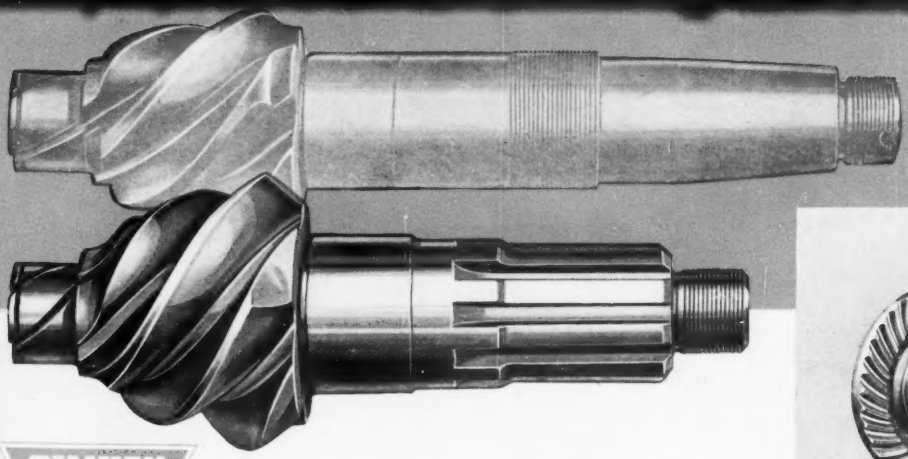
Space given to the STEEL SCRAP DRIVE by . . .

THE STEEL COMPANY OF WALES LTD

ABBEY WORKS · PORT TALBOT



In front, 9-tooth hypoid pinion compared with (at back) ordinary spiral pinion for axle of similar capacity.

TIMKEN AXLES
The Accepted Standard
D T A CO

With Hypoid final drives

Timken-Detroit 'L' Series

Continuing the typical Timken developments, the 'L' series rear axles are available with three types of final drive : Hypoid single-reduction, Hypoid & helical double-reduction, and Hypoid & helical Two-Speed double-reduction. Each type of final drive is interchangeable in the same axle housing using the same axle shafts.

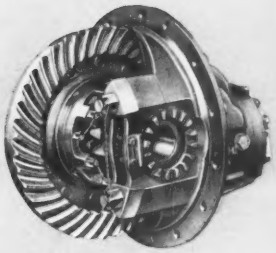
Other features are the Easy-Power gear-shift, stronger differential pinions, the heavy-duty Timken tapered-roller bearings, the forged axle housing of high carbon steel, and improved lubrication.

Track: 71½" for 10 x 20 tyres on dual disc wheels with 13.1" spacing.

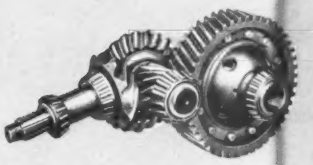
Ratios: Single reduction : choice of $4\frac{1}{9}$, $5\frac{2}{7}$, $6\frac{1}{6}$, $6\frac{8}{9}$, $7\frac{3}{8}$.
Double reduction : choice of 7.22 and 8.22.
Two speed : 6.32 high, 8.22 low.

Brakes: Hydraulic — 16½" x 4" dual.
Air actuated — 16½" x 5".

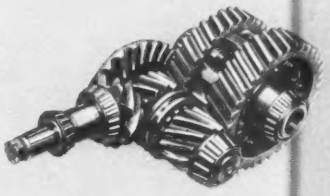
Exclusive European distributors for The Timken Detroit Axle Co., Detroit, Michigan, U.S.A.:
AUTOMOTIVE PRODUCTS COMPANY LTD.,
BROCK HOUSE, LANGHAM STREET,
LONDON, W.1, ENGLAND



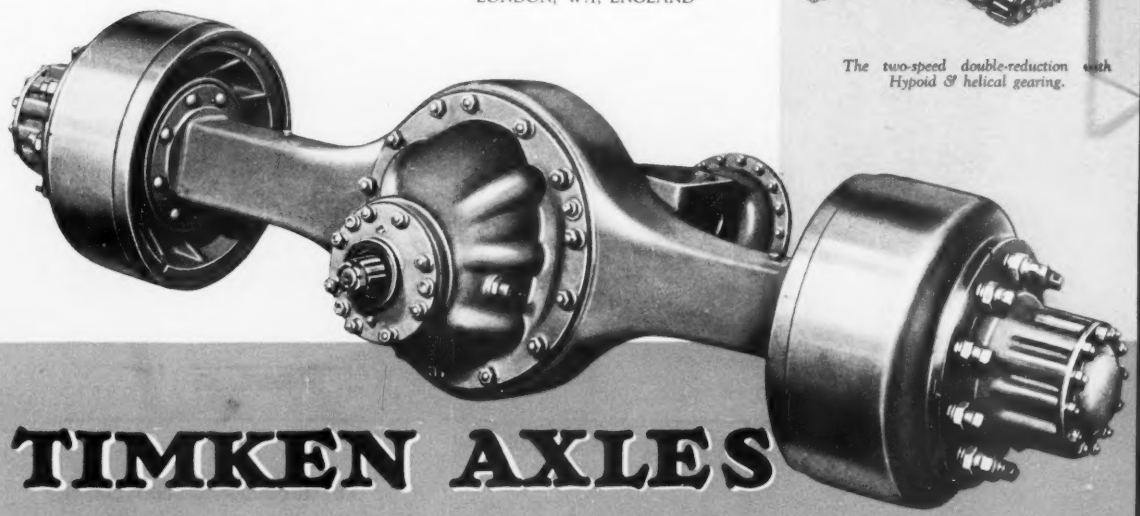
The Hypoid single-reduction final drive has many new exclusive features of design and construction.



Hypoid gearing is used for the first reduction in double-reduction final drive.



The two-speed double-reduction with Hypoid & helical gearing.



TIMKEN AXLES

Such well-moulded features!

Wing ornaments

Ashtray covers

Instrument dials

Gear lever knob

THE SUPERB NEW VAUXHALL features no fewer than eleven Ekco mouldings, both compression and injection. The edge-lit instrument dials are of transparent Diakon; the gear-lever knob, which has an internal thread, is of cream urea; and the flush ash-tray covers and the wing ornaments are of brown and black phenolic respectively. The whole of this moulding programme was carried through smoothly and economically by the Ekco Plastics 'start-to-finish' service, which specializes in making life easier for manufacturers of practically anything. If, then, you have a problem involving one or many different types of moulding, or a production problem to which plastics may provide the solution, you are cordially invited to transfer your worries to the broad backs—and minds—of Ekco Plastics!

EKCO *Plastics for Industry*

Members of the British Plastics Federation and the Society of the Plastics Industries of America

E. K. COLE LTD. (PLASTICS DIVISION), SOUTHEND-ON-SEA, ESSEX

Telephone: Southend 49491

renfrew foundries ltd
Suppliers of
Aluminium Alloy Castings
to the
OFFICE EQUIPMENT INDUSTRY

Making the better motor oils of today...

Every year, millions of tons of oil pass through Shell's refineries—the most modern in Europe. At these plants, the crude oil is subjected to many exacting processes so as to produce the highly refined oils needed for your vehicles. This picture—taken at Stanlow, the Shell Refinery in Cheshire—shows an Evaporating Tower used in the initial stages of the refining.

and tomorrow

At Shell's Research Centre at Thornton, Cheshire—the biggest scientific research centre in Britain—a staff of 900 work constantly to develop the motor oils of tomorrow. Exhaustive laboratory experiment is followed by rigid practical engine tests in which the oils are subjected to extremely gruelling trials *under actual running conditions*. This photograph taken at Thornton, is a view of a supercharged diesel engaged on a 480-hour continuous running endurance test!

SHELL

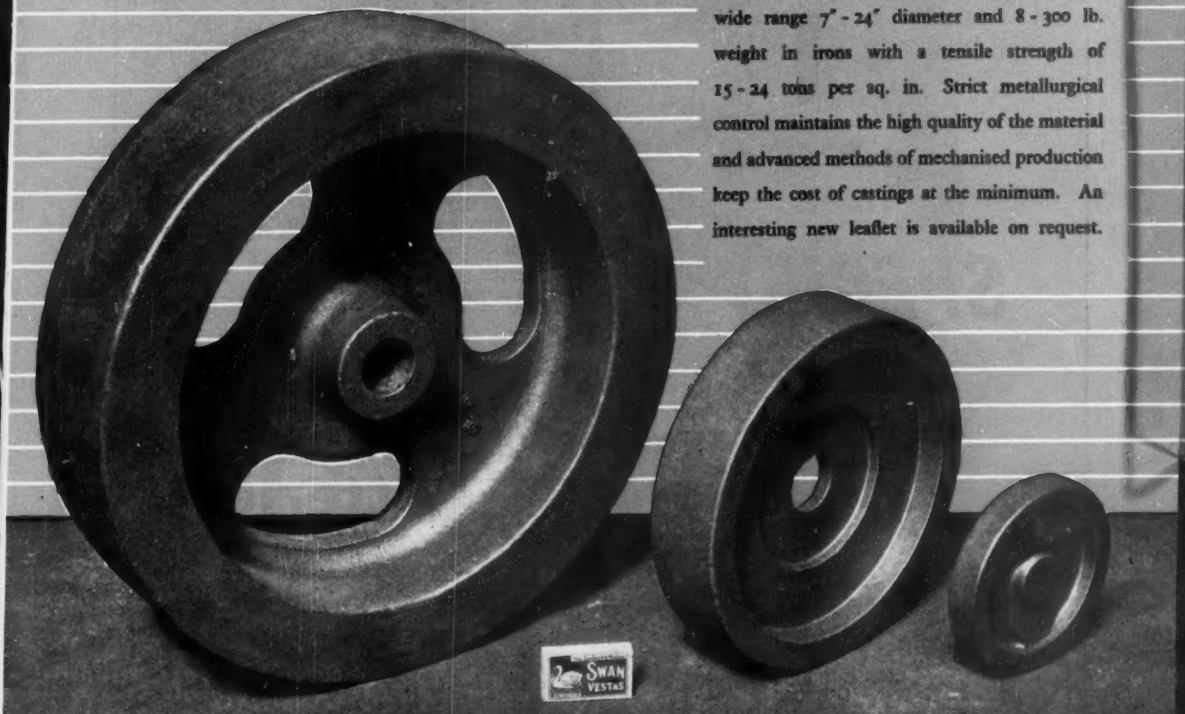
LEADERSHIP IN LUBRICATION

FLYWHEELS
IN CAST IRON

by

DARCAST

Exhaustive tests at high speeds and production and use over a long period have proved the suitability of Darcast Flywheels in high duty cast iron for petrol and diesel engines and for compressors. Long specialised experience ensures homogeneity in the castings which is necessary to obtain uniform density with perfect balance, while the machining faces are free from hot-crazing and suitable for friction clutch operation. Our current production covers a wide range 7" - 24" diameter and 8 - 300 lb. weight in irons with a tensile strength of 15 - 24 tons per sq. in. Strict metallurgical control maintains the high quality of the material and advanced methods of mechanised production keep the cost of castings at the minimum. An interesting new leaflet is available on request.



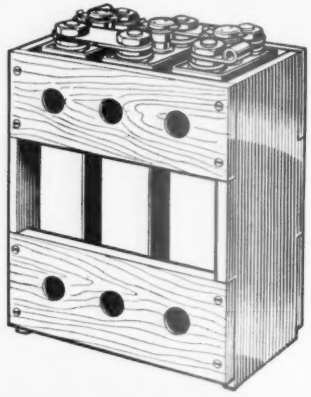
DARTMOUTH AUTO CASTINGS LIMITED

SMETHWICK 40 BIRMINGHAM

Long Term Policy

for Vehicle Starting and Lighting

The expectant life of C.A.V. Alkaline Batteries is equal to that of the Petrol or Diesel engined vehicles in which they are used. The initial cost is higher than for other makes, but considerable saving is effected in the long run, as the all-steel units are practically indestructible. The advantages include :—



Considerable saving in weight.
(In Coaches or P.S.V's.)

No loss of active material from the plates.

Batteries cannot be damaged by overcharging.

Rapid discharge, or even short circuit, causes no damage.

Negligible self-discharge.

No corrosion of terminals.

Gases produced are non-corrosive.

Unaffected by the most severe vibration.

Maintenance costs are practically nil.
The first cost is the last cost.

SPECIFY

C.A.V.

Alkaline **Batteries**

once and for all

C.A.V. LIMITED, ACTON, LONDON, W.3

274-49

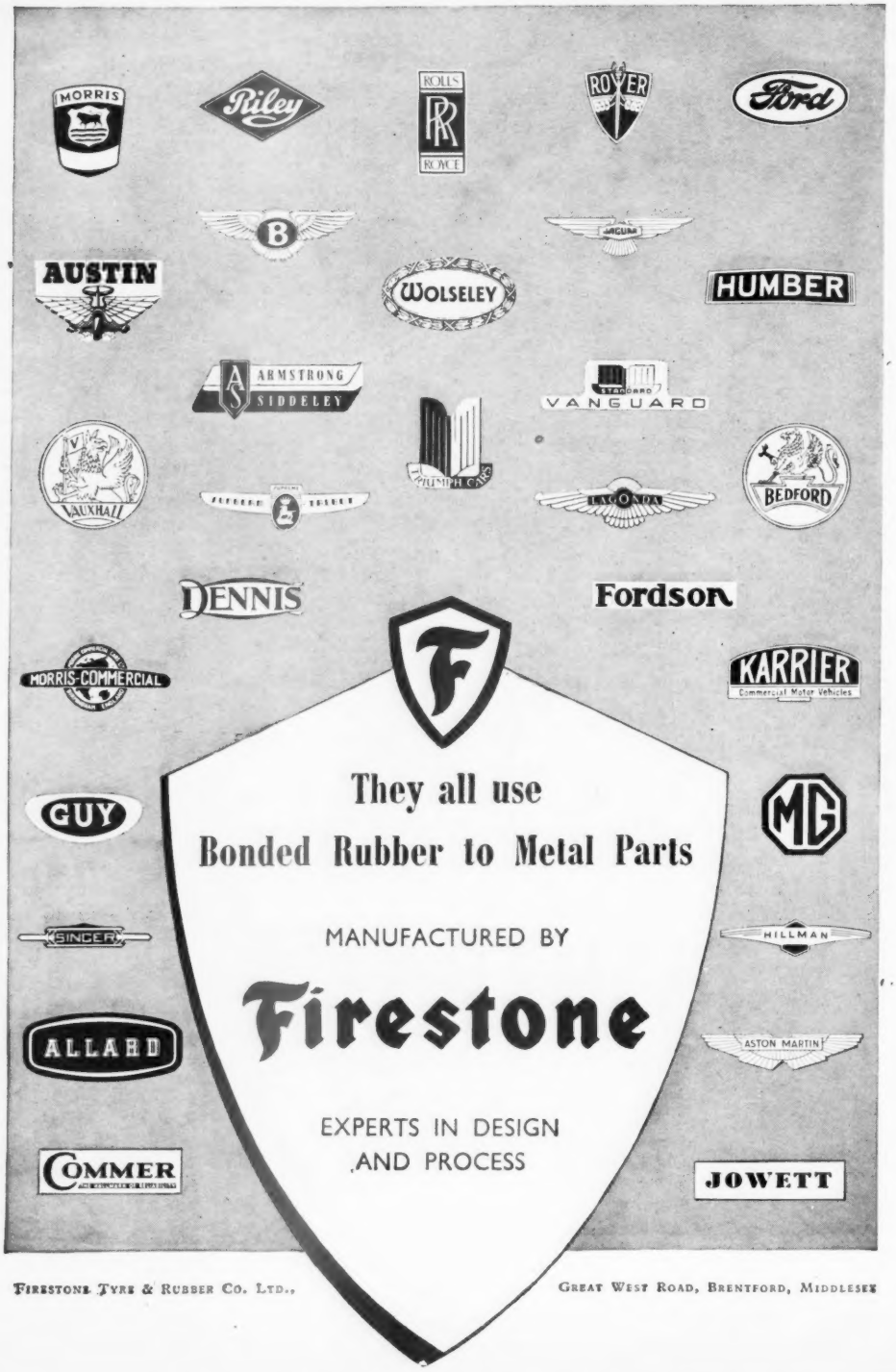
STERLING

Castings for the Triumph Mayflower

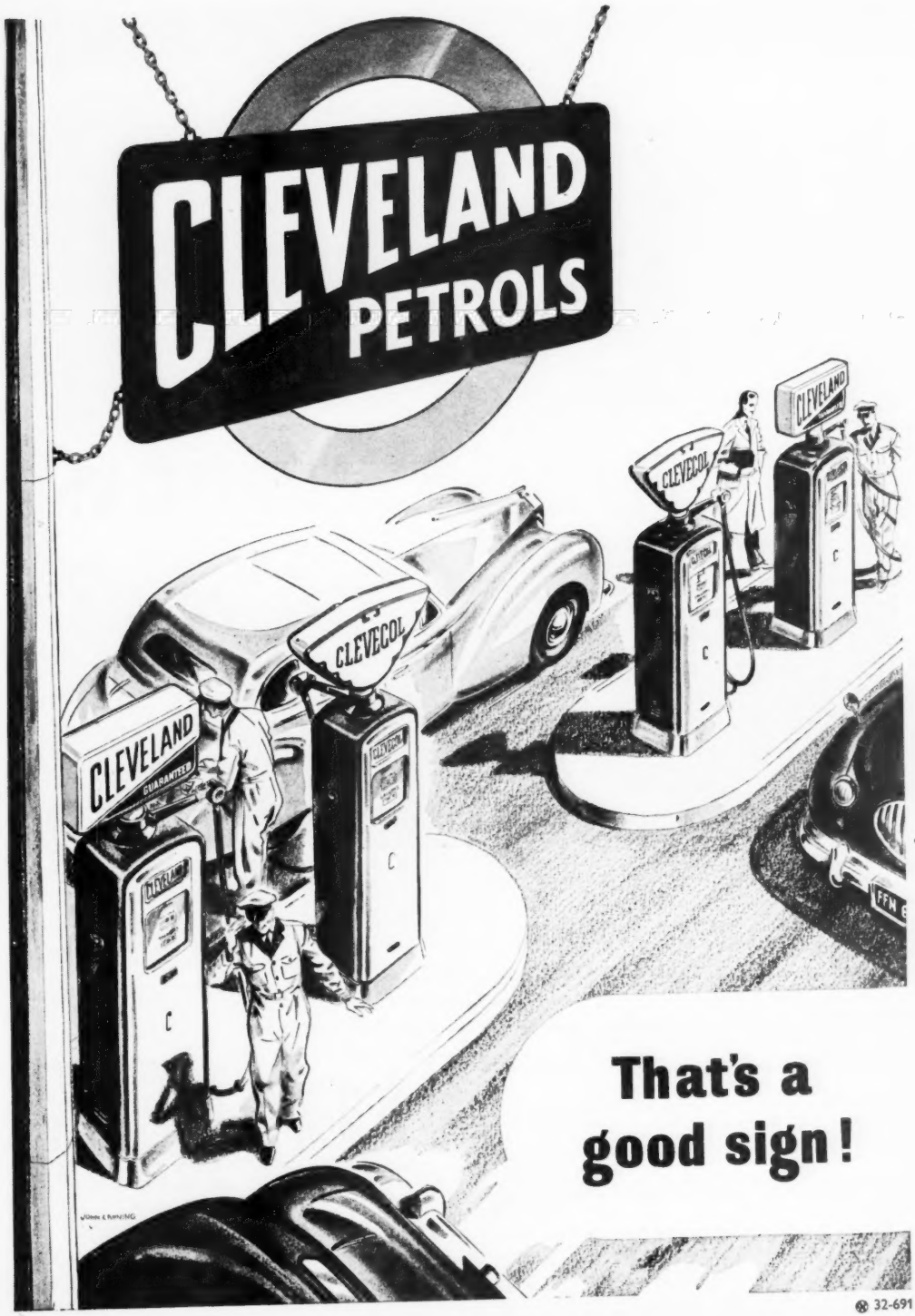
STERLING METALS LTD COVENTRY

By courtesy of the Standard Motor Co. Ltd.

TELEPHONE: COVENTRY 89031 (6 lines) · TELEGRAMS: STERMET · PHONE · COVENTRY



FIRESTONE TYRE & RUBBER CO. LTD., GREAT WEST ROAD, BRENTFORD, MIDDLESEX


CLEVELAND
PETROLS
CLEVECOL
CLEVELAND
GUARANTEED
That's a
good sign!

⊗ 32-691

This is one of the testing machines from the Bury Felt Laboratory. By abrasion on an oscillating platform it tests the toughness and wearing qualities of the selected sample of felt.

Felt, like many other industrial products, must measure up to precise standards of behaviour under particular stress. The Bury Felt laboratory, with its special testing equipment, ensures that all Bury Industrial felts are ready to meet the particular needs for which they have been made. In filters, seals, washers, buffing rollers, shock absorbing mountings and cushionings Bury Felts give a good account of themselves. These are just a few uses of the versatile materials which can be die-cut, chiselled, punched, machined and even ground.

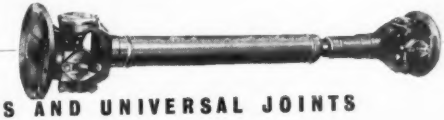
BURY FELT

Send your inquiries to:
BURY FELT MANUFACTURING COMPANY LTD.
HUDCAR MILLS, BURY, LANCS. *Tel. Bury 2262 (6 lines)*
or to the London Office: 3 Snow Hill, E.C.1 · *Telephone: Central* 4448

A hand upraised....

A hand upraised may stop a bus, but consider the effort required to start it again. A tremendous load is thrown on to the transmission. This happens not once but thousands of times in the average daily life of a bus. Designed to withstand this strenuous stop and start routine, Hardy Spicer propeller shafts and universal joints as supplied to the majority of public service vehicle manufacturers are standard fittings —they are standard throughout the motor industry.

HARDY SPICER
NEEDLE BEARINGS



PROPELLER SHAFTS AND UNIVERSAL JOINTS

HARDY SPICER & CO. LTD. (*A Birfield Company*) WITTON, BIRMINGHAM, 6
HARDY SPICER (AUSTRALIA) PTY. LIMITED, SOMERS STREET, BURWOOD, E.13, VICTORIA, AUSTRALIA

Emergency case-hardening steels

MECHANICAL PROPERTIES			"STANDARD" STEELS B.S.970		"EMERGENCY" STEELS ADDENDUM No. 1 B.S. 970	
TENSILE STRENGTH		Izod Impact ft.-lb. min.	En No.	Type	En No.	Type
t.s.i.	kg/mm²					
40–60	63–94	50	37	3% Ni	—	—
45 min.	71	40	33	3% Ni		
,,	,,	,,	34	2% Ni-Mo (lower C.)		
,,	,,	30			351	¾% Ni-Cr
,,	,,	25			361	"15" carbon low-alloy
55–75	86–118	35	36T	3% Ni-Cr		
55 min.	86	,,	325	Low Ni-Cr-Mo		
,,	,,	25	35	2% Ni-Mo (higher C.)		
,,	,,	20			352	1% Ni-Cr
,,	,,	15			362	"20" carbon low-alloy
65–80	102–126	30	36V	3% Ni-Cr		
65 min.	102	,,	38	5% Ni		
,,	,,	20			353	1¼% Ni-Cr
,,	,,	—			363	"25" carbon low-alloy
75 min.	118	20			354	1¾% Ni-Cr
85 min.	134	25	39A	4¼% Ni-Cr		
,,	,,	,,	39B	4¼% Ni-Cr-Mo		
,,	,,	,,	320	2% Ni-Cr-Mo		
,,	,,	,,			355	2% Ni-Cr-Mo (low-Cr)

Eight new specifications for case-hardening steels have been issued by the British Standards Institution. The new steels are intended to replace, as an emergency measure, the more highly alloyed case-hardening steels in current use.

The table gives details, based on mechanical properties, of the new economy steels which are alternative to the standard alloy steels. Many of these standard steels will again be available when the present situation has passed.

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED · SUNDERLAND HOUSE · CURZON STREET · LONDON · W1

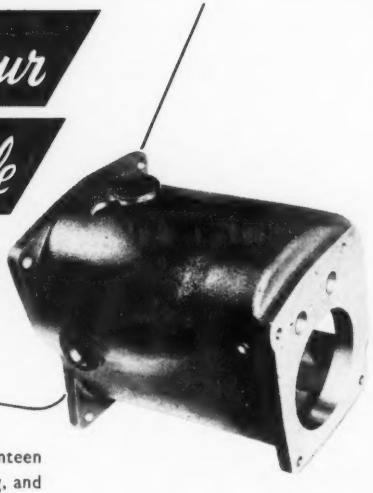
MARBAIX

FOR UNUSUAL MACHINES

1980 Holes Per Hour

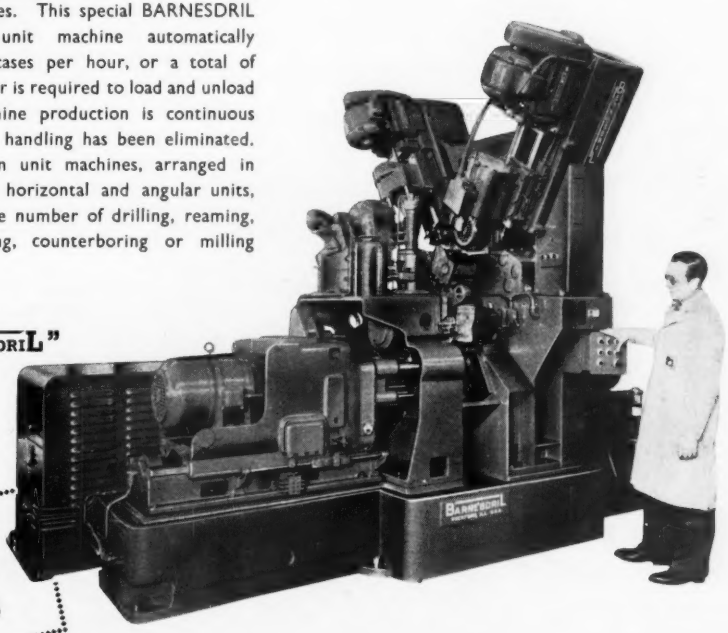
17 Operations Per Cycle

on BARNESDRIL
PRODUCTION UNIT MACHINE



These cast iron transmission cases require seventeen operations for drilling, reaming, chamfering, facing, and tapping a total of 33 holes. This special BARNESDRIL hydraulic production unit machine automatically machines 60 complete cases per hour, or a total of 1,980 holes. The operator is required to load and unload only. As a result, machine production is continuous and a great deal of work handling has been eliminated. BARNESDRIL production unit machines, arranged in combinations of vertical, horizontal and angular units, can be applied to a large number of drilling, reaming, tapping, threading, facing, counterboring or milling operations.

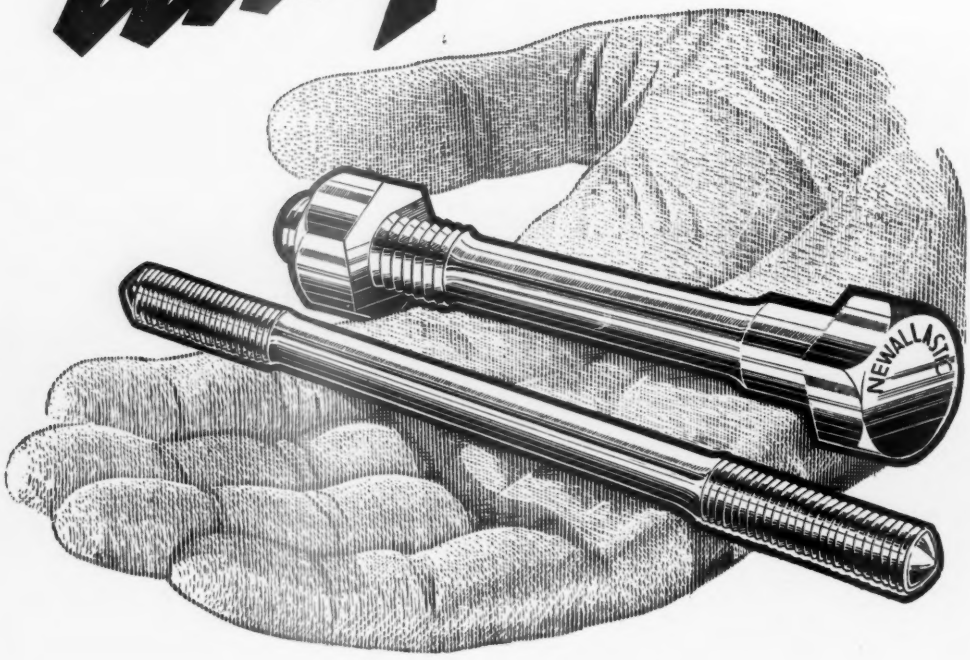
"TAILORED-SKIL by BARNESDRIL"



WRITE FOR BULLETIN No. 150 B

Gaston E. Marbaix Ltd.
DEVONSHIRE HOUSE, VICARAGE CRESCENT, BATTERSEA, LONDON, S.W.11. PHONE: BATTERSEA 8888 (8 lines)

Unique



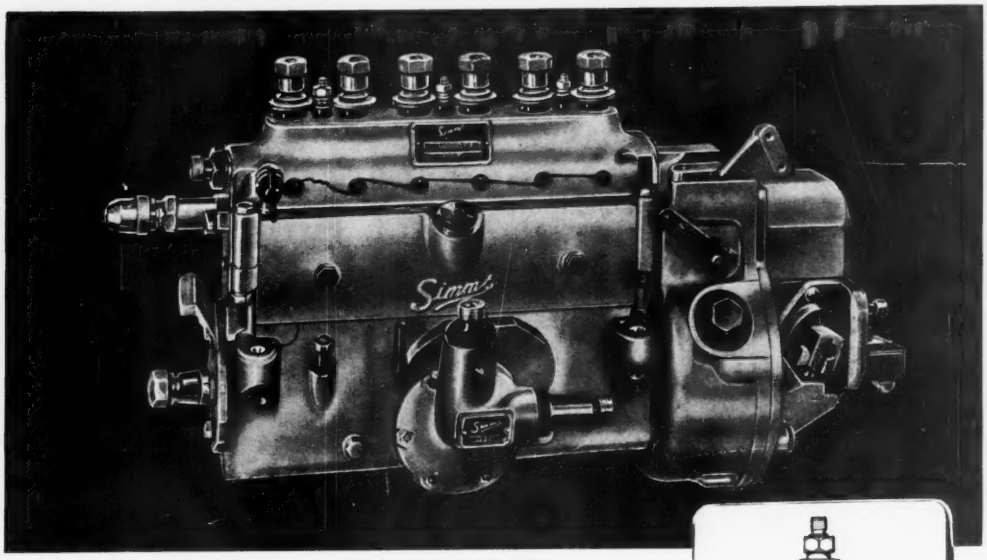
"Newallastic" bolts and studs have qualities which are absolutely unique. They have been tested by every known device, and have been proved to be stronger and more resistant to fatigue than bolts or studs made by the usual method.

C. P. Newall & Co., Ltd.

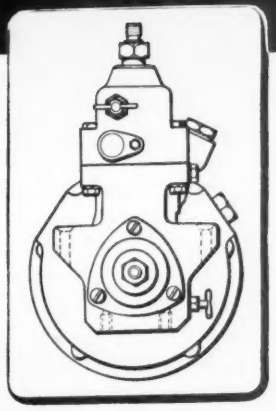
POSSILPARK GLASGOW · N

THINK OF *Enterprise..*

When discussing fuel injection one name comes to mind instinctively—*Simms* . . . for precision manufacture . . . *Simms* for trouble-free governing . . . *Simms* for inexpensive maintenance; spontaneous acknowledgement of the engineering skill and enterprise that evolved the first all-British fuel injection pump.



Fuel Injection Pump, Type SPE, as used extensively on heavy commercial vehicles, railcars, tractors, high-speed marine and industrial engines, etc. Essential dimensions are standard.



THINK OF *Simms* FUEL INJECTION EQUIPMENT

SIMMS MOTOR UNITS LTD

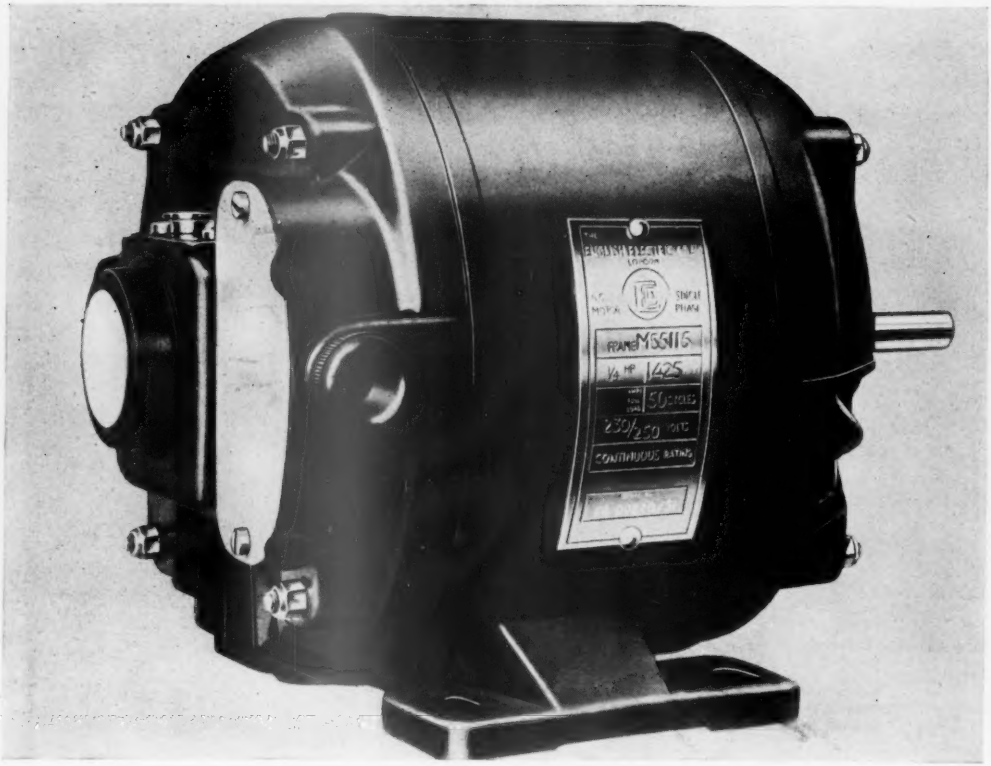
OAK LANE · EAST FINCHLEY · LONDON · N2

Telephone: FINCHLEY 2262 (20 lines) Grams: SIMOTUNIT, EASTFINCH, LONDON

Smeet

'ENGLISH ELECTRIC'

f.h.p. electric motors



Designed for Every Drive

Fractional horse-power motors, A.C. and D.C., ranging from 1/12 h.p. to 1 h.p., are manufactured by 'ENGLISH ELECTRIC' for every type of drive.

They are suitable for a wide range of industrial, commercial and domestic applications and are made in a variety of enclosures which include drip-proof, totally-enclosed, and totally-enclosed externally fan-cooled, with ball or sleeve bearings.

The motor illustrated is a ¼ h.p. sleeve-bearing single-phase type.

The ENGLISH ELECTRIC Company Limited

QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

F.H.P. Motors Department, Bradford

Works: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

FHP.3

OVER ONE MILLION EATON TWO-SPEED AXLES IN TRUCKS TO-DAY

LONGER VEHICLE LIFE · LESS ENGINE WEAR

LOWER OPERATING COSTS · FASTER TRIPS

GIVES AN OVERDRIVE IN EVERY GEAR

LOWER MAINTENANCE COSTS

REDUCES DRIVER FATIGUE

ECONOMY OF FUEL * *

EATON

2-Speed AXLES

AS SUPPLIED TO LEADING MANUFACTURERS

EATON AXLES LIMITED

In association with—

EATON MANUFACTURING COMPANY, CLEVELAND, OHIO, U.S.A E.N.V. ENGINEERING CO. LTD., LONDON, N.W.10 RUBERY OWEN & CO. LTD., DARLASTON

25 VICTORIA STREET, LONDON, S.W.1., ENGLAND

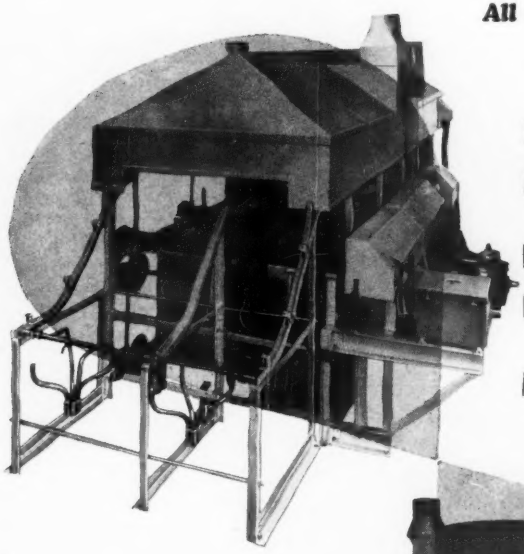
EA.26

points of stress
are strong points . . .
with Smethwick Drop Forgings

SMETHWICK DROP FORGINGS LTD · SMETHWICK & KIDDERMINSTER ENGLAND SDF

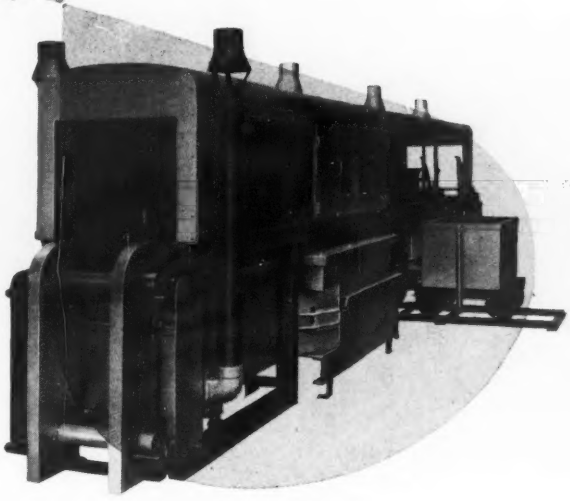
'Cassel' Mechanised Salt Bath Furnaces

for Carburising, Heat-treatment, Austempering, Martempering and Brazing.



All the advantages of the salt bath process plus

- Flow production at high rates
- Less handling and lower labour costs
- Uniform results
- Automatic control of time and temperature
- Elimination of fume and dust



I.C.I. design and manufacture mechanised salt bath furnaces to meet individual requirements. For further information, or for details of 'Cassel' salts and standard types of furnace, consult—

ICI

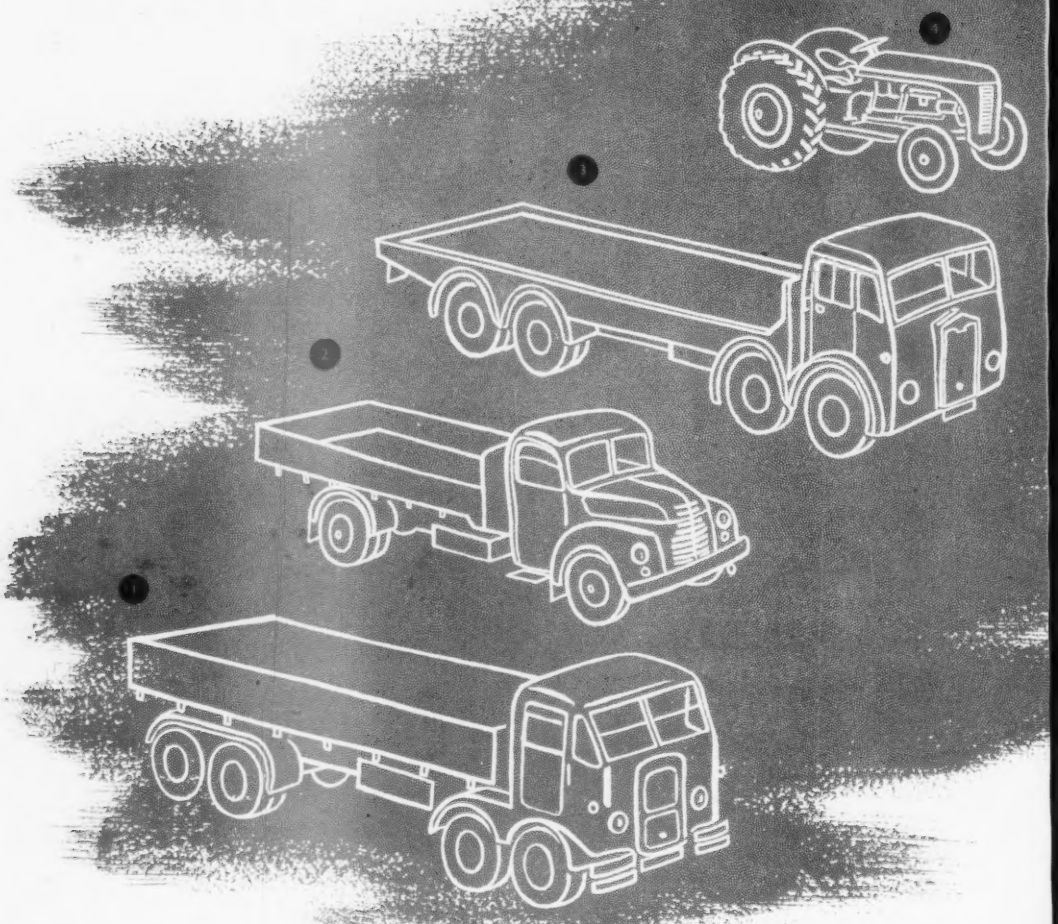
IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON, S.W.1

C.C.155

FIRST!.. AND

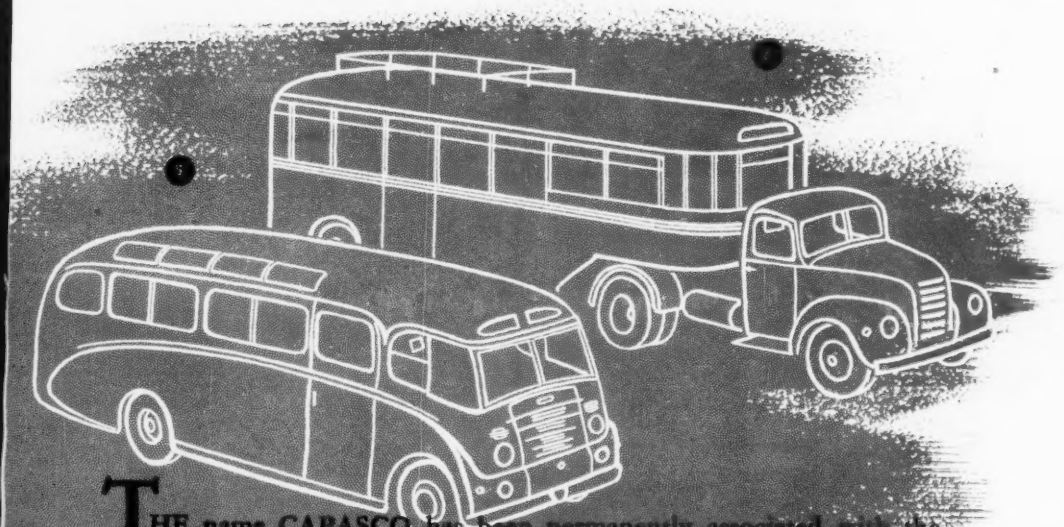
CAPASCO

NON-FADE *Moulded* BRAKE LININGS



1 Scammell 15-ton Rigid 8-Wheeler. 2 Leyland 'Comet 90' Truck Model ECO2.IR.
3 Albion 8-Wheeled Heavy Duty Vehicle. 4 Ferguson Standard Tractor. 5 Tilling-Stevens Express Type. L4MA8. 6 British Trailer Company's Airflow II 50-Seat Semitrailer Coach.

STILL FOREMOST



THE name CAPASCO has been permanently associated with the development and perfection of Heavy Duty Moulded Brake Linings right from the start.

CAPASCO pioneered the way, and is still leading this highly specialised field. CAPASCO Moulded Brake Linings are daily proving their efficiency and reliability under the most arduous conditions and in all forms of Transport.

The illustrations demonstrate clearly a few of the extensive range of vehicles to which CAPASCO is now fitted as original equipment.

★ Press Moulded Homogeneous Structure ★ High Mechanical and Impact Strength ★ Rapid 'Wet' Recovery ★ Extreme Resistance to Frictional Fade ★ Dimensional Stability ★ Uniform Wear to 'Wafer' Thickness ★ Impervious to Oil and Grease ★ Non-abrasive to Brake Drums ★ Suitable for Medium and Heavy Duty Application involving High Temperatures

CAPASCO

NON-FADE *Moulded* BRAKE LININGS

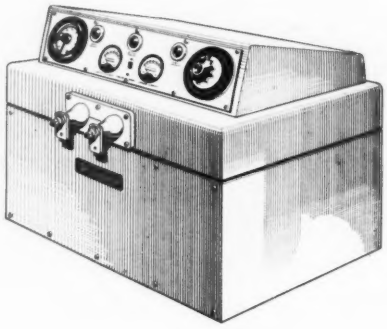
THE CAPE ASBESTOS CO LTD

114 – 116 PARK STREET · LONDON W.1

Phone: GROSVENOR 6022 P.B.X. Grams: "INCORRUPT, LONDON"

Delapena

The World's Best Induction Heaters



Model E15

(15 kilowatts)

Incorporating the latest technical developments, the new Model E15 represents the most modern industrial high frequency heater available.

a) Power output
15 kW on continuous basis
18 kW on intermittent use (75% duty cycle)

b) Oil cooled circuit
this feature enables smaller size, increased reliability and higher efficiency

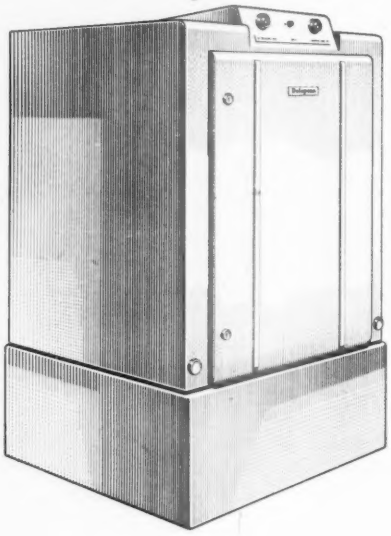
c) Simplicity of design
skilled labour unnecessary. Push button control

d) Remote applicator unit
enables maximum utilisation of floor space in production line

e) Economy
high efficiency ensures low running costs

f) High safety factor
all components are generously rated

g) Load matching
continuous variable on-load power control provided

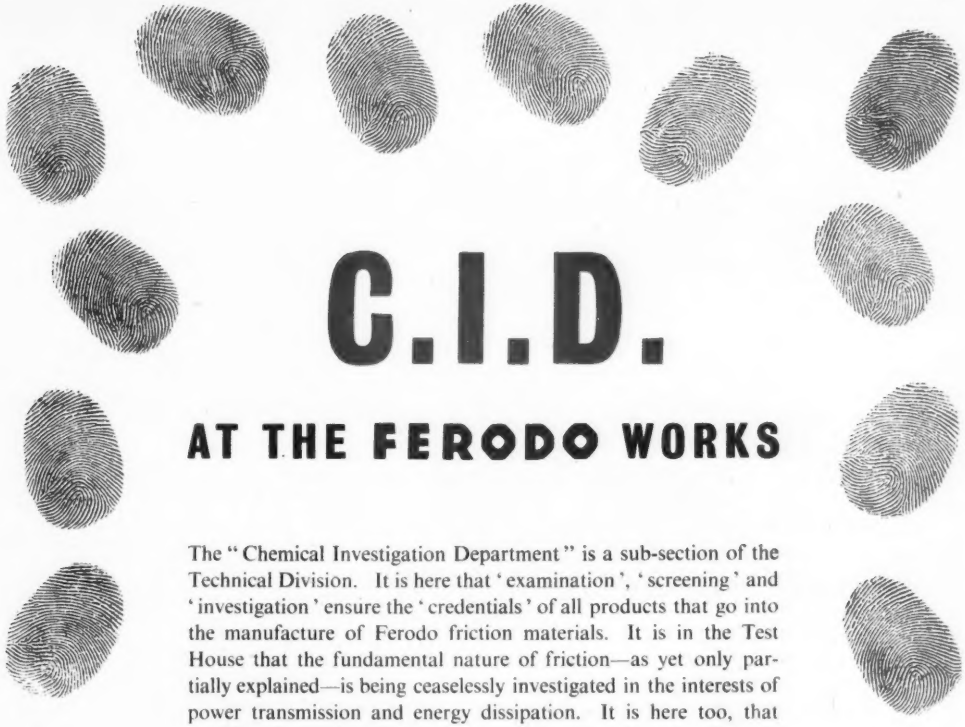


Other models available:

Model E10a	2½ kW
Model E12a	6 kW

DELAPENA & SON LTD., ZONA WORKS, CHELTENHAM, ENGLAND

Telephone – Cheltenham 53866-7-8



C.I.D.

AT THE FERODO WORKS

The "Chemical Investigation Department" is a sub-section of the Technical Division. It is here that 'examination', 'screening' and 'investigation' ensure the 'credentials' of all products that go into the manufacture of Ferodo friction materials. It is in the Test House that the fundamental nature of friction—as yet only partially explained—is being ceaselessly investigated in the interests of power transmission and energy dissipation. It is here too, that samples of every batch of output are subjected to drastic endurance and efficiency tests. But it is on the M.I.R.A. track (of which Ferodo Limited are one of the largest users) that the final and practical proving of the finished product takes place.

British and Overseas Automobile Engineers and Designers are freely and cordially invited to make full use of the Test House facilities so that at first hand the problems associated with ever increasing h.p. and speed can be considered, discussed and solved.

FERODO

BRAKE & CLUTCH LININGS

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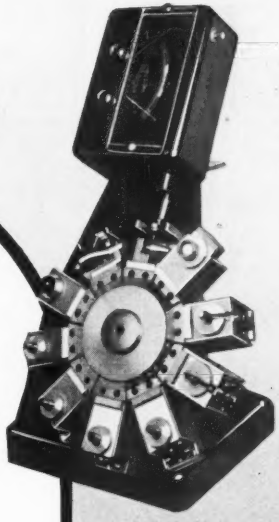

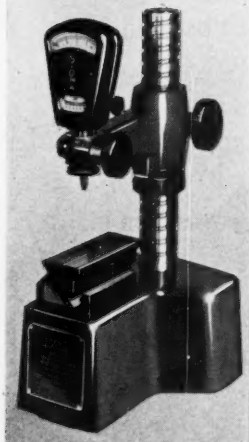

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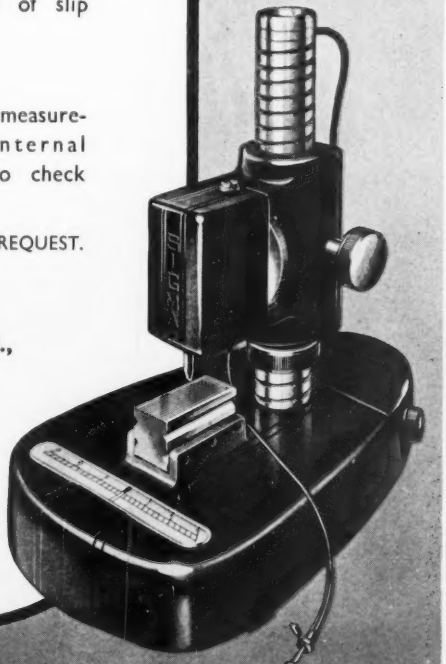

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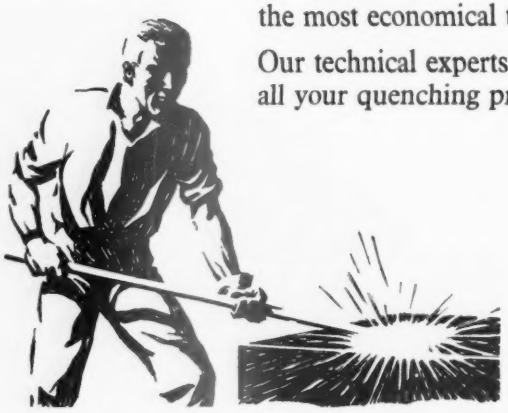

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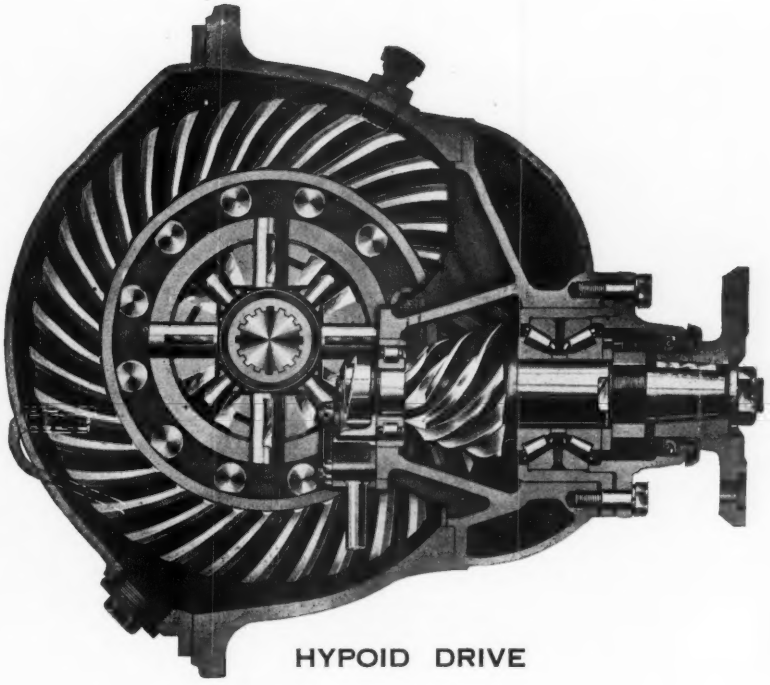

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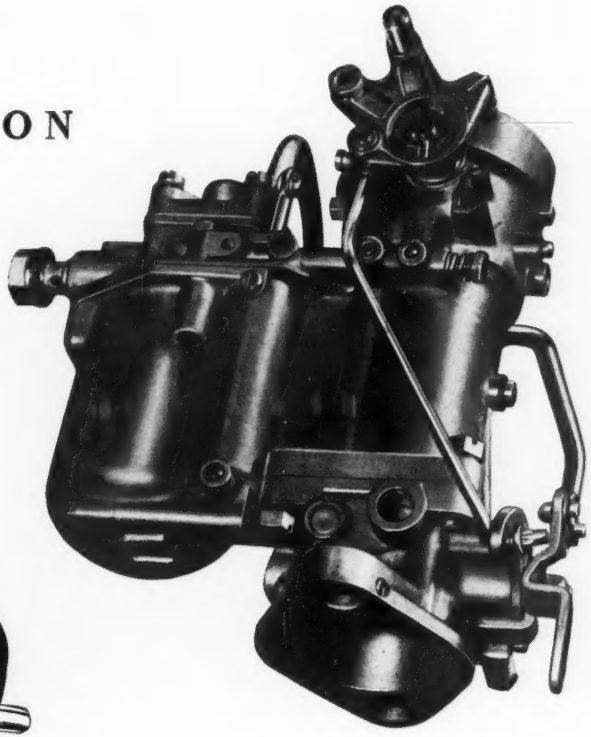

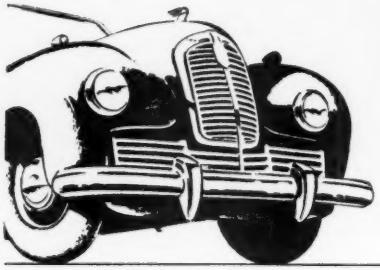

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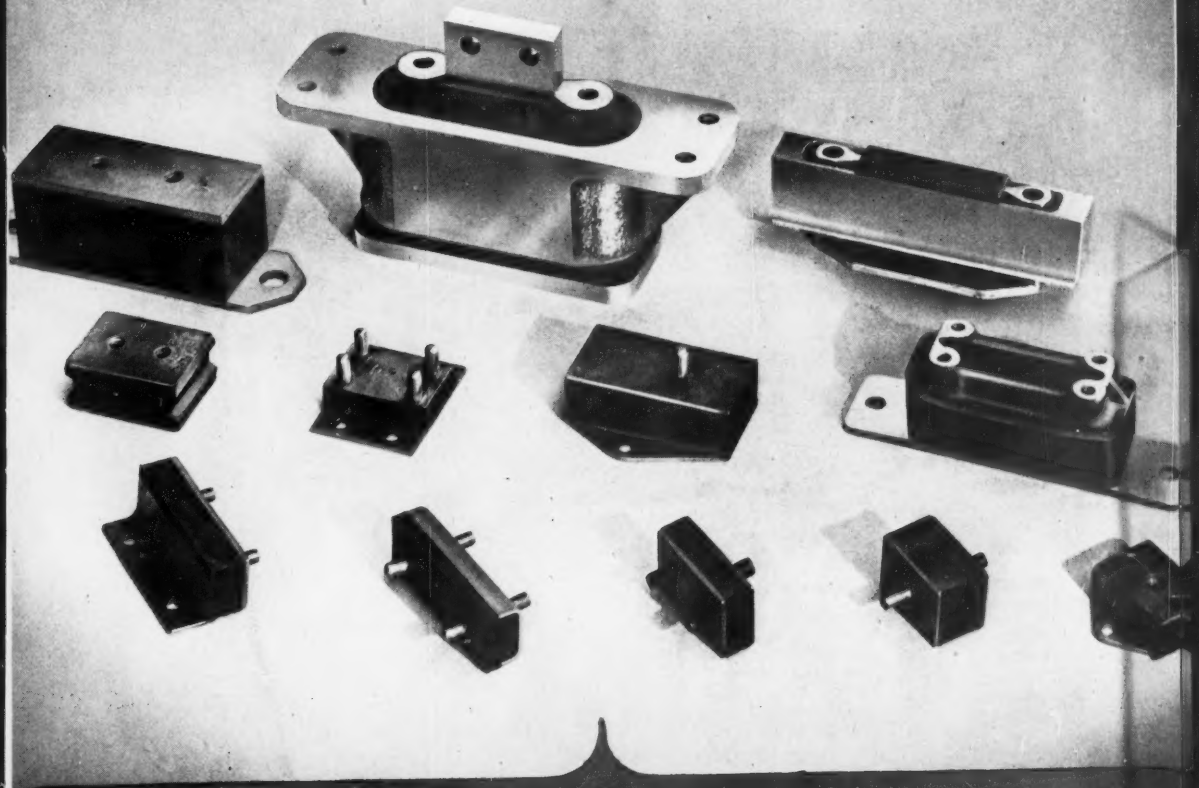

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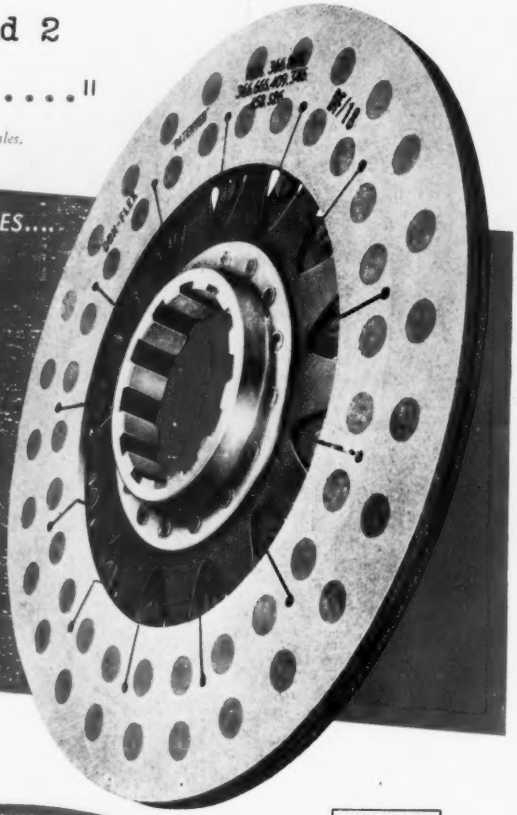

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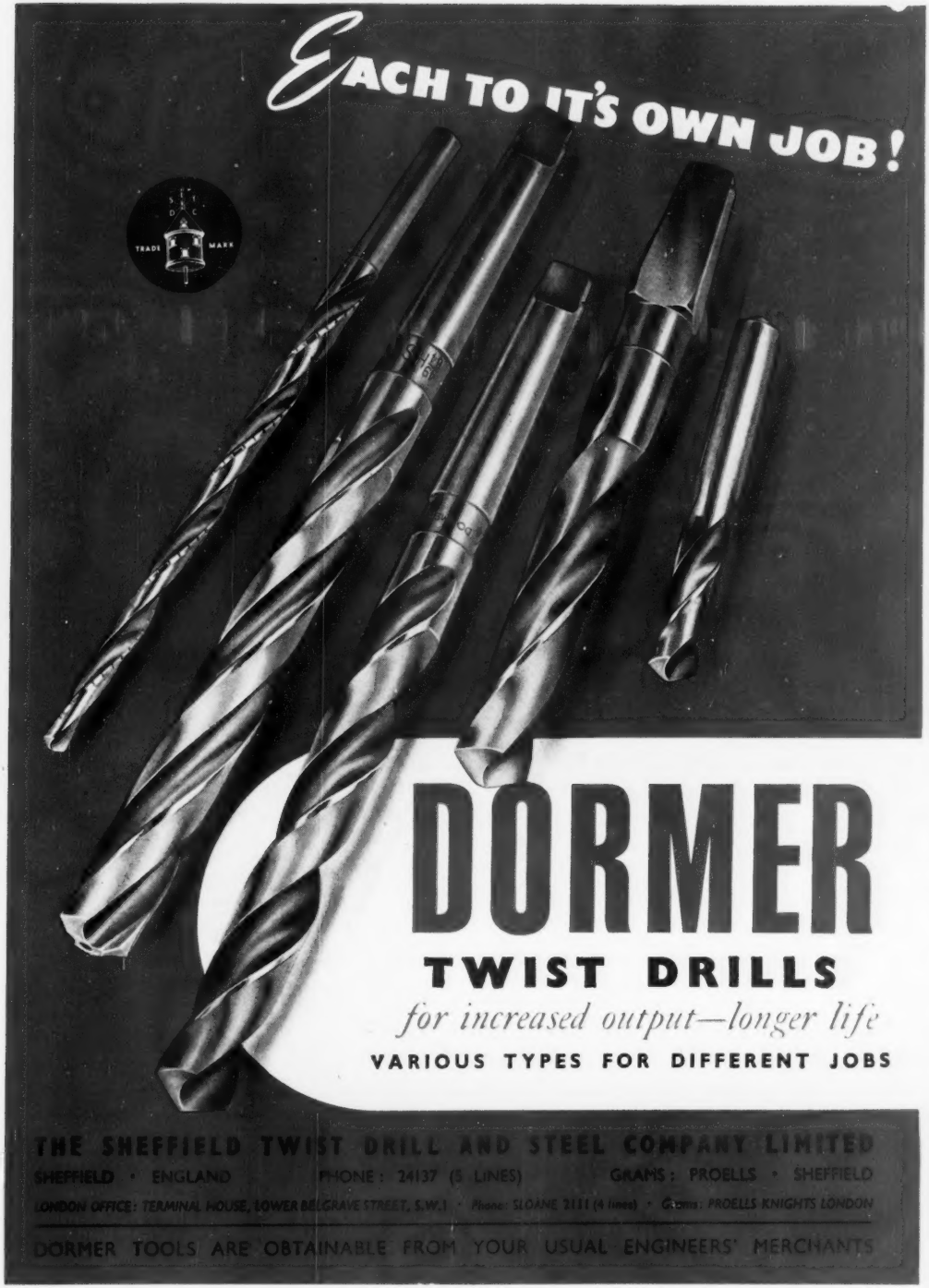
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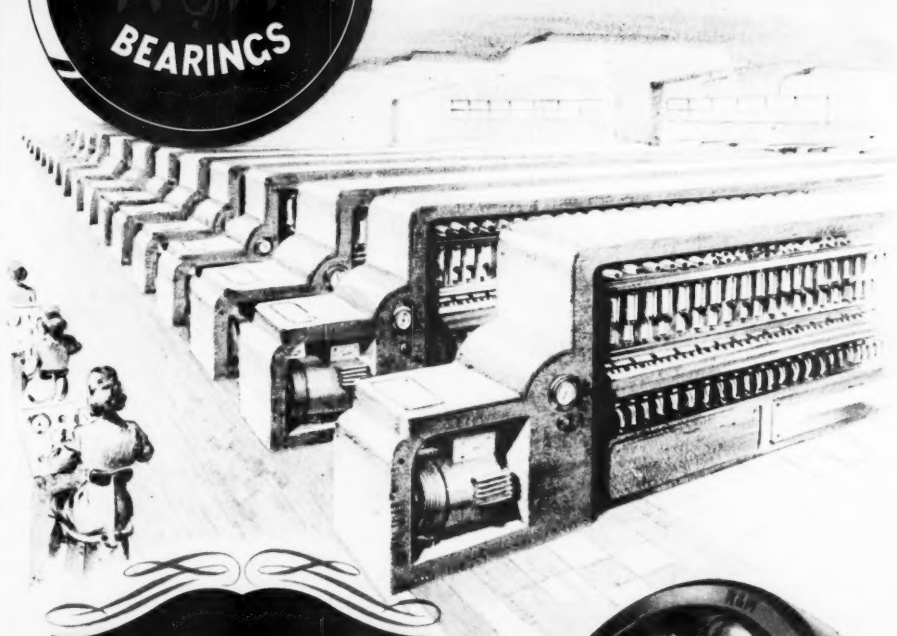

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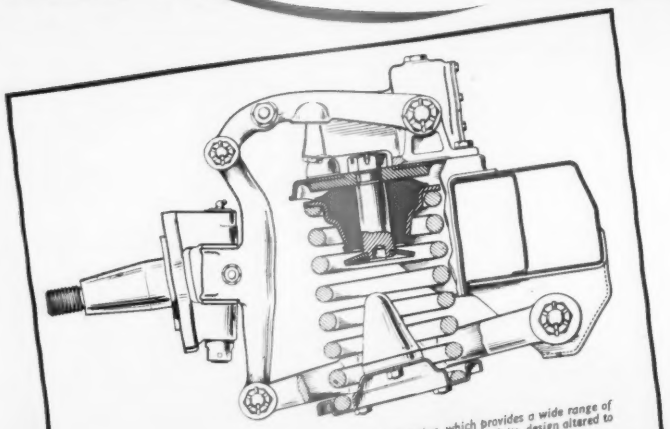
The 'Frustacon' mounting fitted to the I. F. S. of the 1952 Rover '75'. Sectioned to show rubber.



Silentbloc "Frustacon" fitted in an I.F.S. System. The mounting, which provides a wide range of deflection rates, may be fitted at the top or bottom of the coil spring and its design altered to suit any system.

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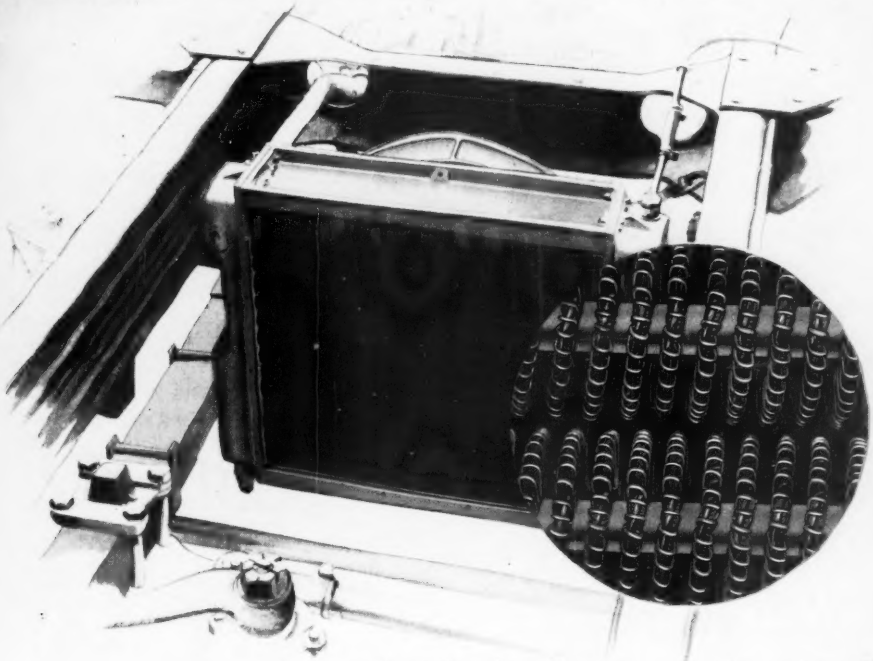

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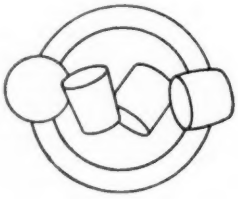

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Light Commercial Vehicles

THE introduction of chassisless and unitary construction vehicles has caused manufacturers to give much thought to problems connected with the design of light commercial vans and pick-ups. Previously, many vehicles of this type were specifically designed to suit the chassis of passenger cars in production at the time. By making not only the chassis but also many of the body panels and components at the front end common to both passenger cars and light commercial vehicles, it was possible to build at an economic cost those types for which the demand was small compared with that for passenger cars.

One of the principal arguments against the introduction of the lighter forms of construction that dispense with separate chassis frames has been that with these new structures it is not possible either to build commercial vehicles on the same basic structure or to supply basic units on which coachbuilders can put bodies of their own design. This is, in fact, an over-statement. Experience has shown that with both unitary and chassisless construction, conversion to other types of bodies is not so difficult as would at first appear. The important thing is to bear in mind, in the initial design stages for the passenger vehicle, that other versions may be required later.

Circumvention

There are two ways of approaching the problem. One is to retain almost all the structure forward of the front seat and build integrally with it a chassisless rear end suitable for a commercial vehicle. This method is perhaps most easily applied to vans, and it is certainly not impossible to use it in designing a pick-up vehicle.

The other method is to retain most of the front end structure, but to integrate with it a more or less conventional frame, under the floor and projecting to the rear, to support the back end. Care must be taken at the junction between the front and rear parts to ensure that the structure is adequate for transferring the loads from the frame to the chassisless portion of the vehicle.

Certain forms of chassisless construction for passenger cars do not lend themselves to conversion. For such, there is a method of overcoming, or rather circumventing, the problem that has much to recommend it. The commercial version may be designed specifically as a van with an entirely separate chassis frame that can accommodate many of the sub-assemblies. Thus, major components, including the front suspension unit mounted on its cross member, are common to the van and the passenger car.

When a passenger vehicle is converted to a commercial type, of necessity the result is a compromise. As such, it can scarcely ever be ideal. For example, weight distribution is usually unsatisfactory. To improve it the frame often has to be lengthened. This entails modifications to all components that extend over the major part of the length of the vehicle. Moreover, the frame itself may not be sufficiently strong to carry the extra loads it will be called upon to take.

Apart from purely structural requirements, there are other factors which point to the need for an entirely new approach to light van design. Floor space is important in commercial vehicles, whereas in a passenger car the width at seat and shoulder height is the governing factor. The maximum capacity is generally required in light commercial vans while in passenger cars head room and all-round vision are desirable. Further, in order that passenger cars may attain high speed, reasonably efficient streamlining is necessary, but in a light van streamlining is unnecessary and would also restrict space.

For a commercial vehicle, as for a taxi, manoeuvrability is desirable. This can be incorporated in a specialized design. Lock-to-lock movement of the front wheels can be increased, subject to limitations imposed by the requirements for pedal room between the wheel arches. A short wheelbase may also be employed to improve manoeuvrability, but here again there is a limitation. The load has a relatively high centre of gravity so that the K^2/ab ratio is increased. This will result in uncomfortable riding conditions, which if long journeys are involved, may even be unbearable.

Braking problems

Brakes require special attention in vehicles that are constantly stopping and starting. Wear and tear is much greater in delivery vehicle brakes than in passenger cars. To overcome this, the lining areas should be increased. It is perhaps easier to use a lining with greater wear resistance, but this may cause troubles in service. Nor is the brake trouble experienced in operation confined only to linings. The whole brake control system should be designed for heavier duties. This applies particularly to the hand brake system, for which the lever type is preferred. Another factor that influences the braking requirements

for a commercial vehicle is the type of load that is carried. If the centre of gravity is high, the weight transfer to the front wheels, when the brakes are applied, will be greater than in passenger cars, and vice-versa if it is low. In view of the diversity of loads carried, it is probably impossible to set the brakes to suit all operating conditions. It is therefore, desirable that a simple method of adjusting the front : rear ratio is incorporated in the design.

Another component that is required to perform a more arduous duty on delivery vans is the clutch. Here again, a larger friction area is desirable. An easier, though less satisfactory method is the incorporation of stronger springs with heavy-duty linings. On short runs in cold weather, engines are often run at lower temperatures than those for which they are designed. Oils of lower than normal viscosity should, therefore, be recommended to operators who use their vehicles under such conditions. This also applies to transmission components such as gearboxes and axles. It is almost unnecessary to say that the axle ratios should be selected to suit the vehicle and its duties.

Industrial Resilience

FROM infancy to maturity, the motor industry has been evolved in the last half-century. Having no deep-rooted traditions from the past it readily acquired the outstanding characteristic of the period—that of change. Indeed, it was itself a major factor influencing change in the social and industrial life of the country. Accordingly, it developed a remarkable flexibility and an ability to adapt itself to varying conditions. This capacity was demonstrated in no uncertain fashion in the two world wars.

The motor vehicle and the internal combustion engine are truly ubiquitous. Throughout the world, they have proved to be essential for transport and communications, in peace or in war, in tropic or arctic climate. In undeveloped countries the need for motor vehicles is as pressing as in highly industrialized countries, or even more urgent. Such a demand can only be met by large-scale production and, to be economic, large-scale production must be continuous. These facts, it may be suggested, are self-evident and do not need to be stressed. Were they more generally accepted, however, the motor industry might expect to receive more consideration at the hands of governing authorities, both at home and abroad.

In Britain, the industry has achieved first place in the field of exports and is one of the mainstays of our defence programme. It is still urged to expand its capacity and increase its productivity but is rationed in its supplies of raw material, heavily taxed and subjected to further handicaps such as increased fuel taxes whenever it is desired to raise more revenue.

Overseas, the imposition of currency, credit, tariff or import restrictions are made suddenly and arbitrarily against motor vehicles as economic conditions fluctuate. The motor industry has become the sport of the nations.

Despite the resilience of the industry, such treatment interrupts production, and involves waste of resources and of effort. Both at home and in the international field it would seem that the motor industry, supported by the user interests, could exert sufficient influence to ensure a relative improvement in stability that would be to the advantage of all. The industry does not need to be regarded as the spoilt child of modern economic life but it should not allow itself to be treated as a whipping boy.

Future trends

To look, or even to hope, for complete stability would be unrealistic. During the lifetime of the industry two world wars have shaken all countries to their foundations, and reverberations and repercussions must be expected for many years to come. Doubtless changes in manufacturing and marketing policies will need to be made and, equally doubtless, the industry will be able to meet or even to anticipate requirements.

Two trends are already becoming apparent. One of these, arising mainly from the shortage of steel and other materials, is to arrange for the manufacture under licence of various items of auxiliary or ancillary equipment at plants in the countries to which vehicles are exported. This policy is being energetically pursued by certain tractor manufacturers. The other aims to meet national aspirations by shipping vehicles in completely knocked down condition for assembly at local plants in the importing countries. It is also of value as it offers the prospect of reduced freight charges.

It may not be possible to exploit this policy fully with an established design of vehicle. Obviously, the most careful consideration should be given in any new design, or any modification of an existing model, to ensure that a C.K.D. policy can be advantageously realized. These three initial letters are likely to assume some importance in the industry in the not remote future.

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2½-LITRE LEA-FRANCIS ENGINE

A Power Unit for the 18 h.p. Saloon and 2½-Litre Sports Chassis

SHORTLY after the War, the introduction of the flat rate tax for all new cars made it appear obvious that there would be a demand for larger engines in cars of the type offered by small manufacturing companies producing the more expensive class of popular vehicle. Consequently, Lea-Francis Cars Ltd., of Coventry, in redesigning their chassis to suit post-war conditions, wisely decided that it should be powered by a unit of 18 h.p. as expressed by the R.A.C. rating formula.

The 18 h.p. and 2½ litre engine specifications are given in the panel. From these it can be seen that the stroke : bore ratio is a little higher than 1·29 : 1, and the connecting rod length : stroke ratio is just under 1·98 : 1, both figures being higher than is usual in current designs. Accordingly, when maximum b.h.p. is developed, the mean piston speed is 2,890 ft/min. The maximum b.m.e.p. of the saloon version is 138 lb/in², while that of the sports model is given as 140 lb/in², both values being obtained at 2,500 r.p.m. In terms of b.h.p. per square inch of piston area, the performance of both models is good, the figures being respectively 2·73 and 2·84 for the saloon and the sports.

So far as general layout is concerned, this engine is probably unique. The overhead valves, inclined at an included angle of 80 deg, are operated by twin camshafts, one for the inlet and the other for the exhaust valves, carried high on each side of the cylinder block casting. Not only does this arrangement, patented by Lea-Francis, enable the whole of the cylinder head and valve operating mechanism to be removed together in one simple operation, but in conjunction with the use of hemispherical heads, this layout also makes it possible to position the spark plugs between the valve ports. These are served by almost straight inlet and exhaust passages in the head. Furthermore, the weight of the push rod assembly is appreciably less than in most other designs, so that wear and other undesirable effects of inertia are reduced considerably, and lighter rockers and rocker spindles may be used. Because of the short length of the push rods, their thermal expansion is small. As a result, tappet adjustment is more positive than with most other layouts. On top of the cylinder head, four separate boxes house the rockers which are mounted, in pairs, on four spindles, one in each box. This differs from the 14 h.p. engine in which two rocker covers are employed, one on each side of the head.

On the right-hand side of the engine is the inlet manifold. Below this, bolted to the crankcase is an oil filter in front of which is an oil level dipstick, carried in an adaptor bolted to a boss on the sump. The dynamo is slung from pivot mountings, one being a boss on the timing cover through which a bolt passes to carry the front flange of the dynamo, and the other mounting, bolted to the top of its rear flange, is a bracket on a boss on the cylinder block. To allow for adjustment

SPECIFICATION

18 H.P. ENGINE: Four cylinders. Bore and stroke 85 mm × 110 mm. Swept volume 2,496 cm³. Maximum b.h.p. 95 at 4,000 r.p.m. Maximum b.m.e.p. and torque, 138 lb/in² and 140 lb-ft at 2,500 r.p.m. Compression ratio 6.0:1. Three-bearing, counterbalanced crankshaft of alloy cast iron. Overhead valves, with patented twin camshaft operating mechanism. Single S.U. H.6 horizontal carburettor, 1¾ in choke.

2½-LITRE ENGINE: Cylinder dimensions crankshaft and valve gear are common with the 18 h.p. engine. With 7.0:1 compression ratio, maximum b.h.p. 100–105 at 4,000. Maximum b.m.e.p. and torque 140 lb/in² and 142 lb-ft. Twin S.U. H.3 horizontal carburettors, 1⅜ in choke. A special piston, and a camshaft with high lift cams may be fitted to give a 7.63:1 compression ratio and a maximum b.h.p. of 120-125 at 5,200 r.p.m.

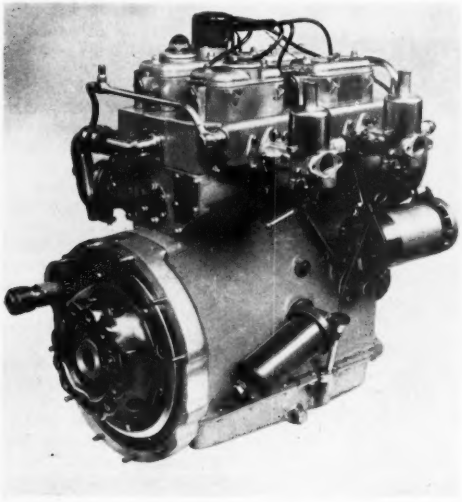
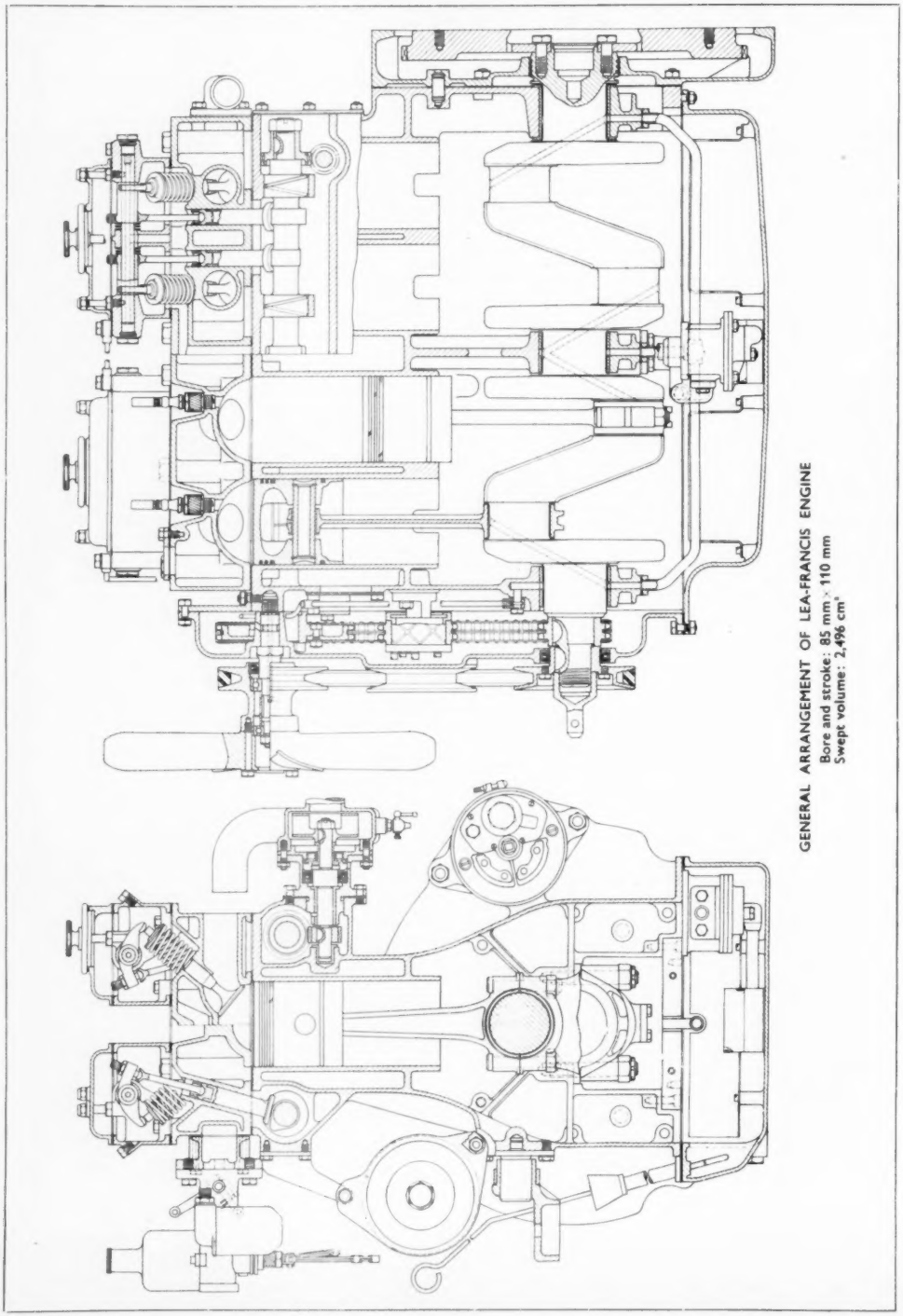


Fig. 1. A water jacket along the inlet manifold forms part of the coolant by-pass system

Fig. 2. The water pump is at the rear on the left, giving a direct rear-to-front cooling flow in the head



GENERAL ARRANGEMENT OF LEA-FRANCIS ENGINE
Bore and stroke: 85 mm × 110 mm
Swept volume: 2,496 cm³

to the tension in the driving belt, one end of a slotted link is secured to the lower part of the front flange, and the other end to the timing cover.

The drive for the dynamo is the usual triangulated V-belt arrangement. However, the third pulley carries only the fan, the water pump being driven by a spiral gear fitted on the left-hand side camshaft. Another spiral gear, machined on the centre of the same camshaft, engages the vertical drive gear for the oil pump, and contact breaker and distributor unit.

This gear is housed in a semi-cylindrical protuberance on the side of the cylinder block casting. It is situated between the two arms of the Y-shaped portion of the exhaust manifolds. In front is the ignition coil bolted to the side of the cylinder block, and to the rear, beneath the water pump, is the starter motor mounted on the flywheel housing.

The engine mounting details are unusual. Provision is made on each side of the crankcase, at the front, for two bolted-on, $1\frac{1}{4}$ in diameter trunnions. Carried on each of these is a boss integral with a sturdy malleable iron fitting that forms an inverted cup-shaped centre-piece of a rubber-iron-rubber sandwich, which is held between a pressed steel, dished rectangular plate at the top and a pressed steel, L-section bracket at the bottom. Around the boss, which is split parallel to its axis is a clamping ring tightened by a $\frac{5}{16}$ in diameter bolt. In plan view, the centre-piece is rectangular in shape, as is the rest of the sandwich assembly above and below it. The major axis of this rectangular part of the mounting is set at an angle of 25 deg to the longitudinal axis of the vehicle, so that the L-shaped pressed steel bracket, carrying the lower rubber, may be slung squarely on the front diagonal frame-bracing member.

The whole assembly is held together by a $\frac{7}{16}$ in B.S.F. bolt passing from top to bottom, the hole for it in the centre-piece being $\frac{3}{4}$ in diameter so that the rubber, compressed by the bolt, is forced around the shank. Similarly, there is a hole $\frac{9}{32}$ in diameter in the lower bracket beneath which is a rubber washer, $\frac{1}{4}$ in thick, to separate the bracket from the bolt head and retaining washer. Thus, there is positively no metallic contact between the engine and the chassis frame. Movement in the horizontal plane is restricted by the rectangular cup-shape of the centre-piece into which is registered the lower rubber, and around which are downward-projecting flanges of the upper rubber, separating it from the L-bracket.

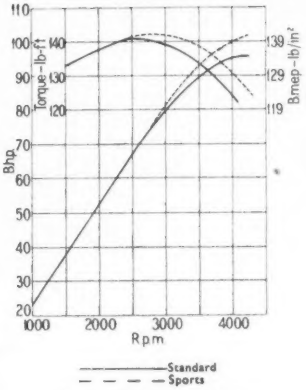


Fig. 4. Engine power curves

The rear engine mounting is a simple steel-rubber-steel sandwich unit. Its upper members are brackets cast one on each side of the gearbox rear cover, and they are set at an included angle of 120 deg. Pressed steel brackets mounted on the frame diagonal bracing structure form the lower members.

Cylinder block and crankcase

The cylinder block and crankcase are integral, and are of cast iron. On each side, at the top, is a cast-in cell for a camshaft. Bosses on transverse webs in each cell are bored to form four of the camshaft bearings, the fifth one being in the front crankcase wall. The lower part of each web is cored out to allow free passage of lubricating oil, and to facilitate the removal of the core after casting. A joint face is machined on the casting at the rear of each cell for a bolted-on $\frac{3}{32}$ in thick closing-plate, sealing being effected with an Oakenstrong joint-washer.

Generous water passages are provided around the cylinders, the minimum space between both the front and the rear pairs being $\frac{1}{4}$ in, while there is $1\frac{3}{8}$ in between the centre pair. The cylinder walls are approximately $\frac{7}{32}$ in thick, and their bores are machined with a single-point tool and hone finished. On each side, part of the lower edge of the cylinders is cut out to clear the connecting rods.

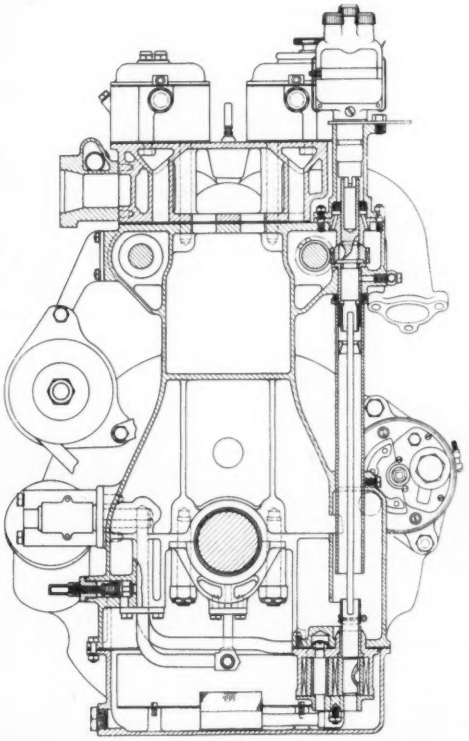


Fig. 11. A tube, between the camshaft cell and the crankcase, houses the oil pump vertical drive spindle

At the front of the crankcase is a machined face to which is secured, by twenty one $\frac{1}{4}$ in diameter bolts, the cast aluminium front cover. This is extended above the cylinder block to enclose the two half-speed wheels. It has, therefore, been necessary to bolt a cast aluminium make-up piece on the top face of the block immediately behind the timing cover to complete its closure at the rear. The face joints are all sealed with Hermetite. A flange on the bottom of the cover is bolted to a forward extension of the sump flange, where the seal is made with an Oakenstrong washer, $\frac{1}{32}$ in thick.

On the crankcase rear wall is a machined face for the bolted-on flywheel housing of cast aluminium. The housing is positively located by three $\frac{1}{2}$ in diameter

Fig. 7. Compression ratio is governed by the shape of the piston crown

dowels, as it must be accurately centred around the oil return scroll on the rear of the crankshaft. An aluminium bridge-piece is secured in a recess in the lower edge of the rear wall of the crankcase by countersunk screws, and no special measures are taken to seal the ends. It is well clear of the main journal cap as the lower joint face, to which the sump is fitted, is at a level 4¼ in below the axis of the crankshaft. Each of the three cast iron bearing caps is recessed into its web to provide positive lateral location. They are secured by $\frac{9}{16}$ in diameter, En 16V studs with slotted and split-pinned nuts.

Crankshaft, connecting rods and pistons

The nickel iron, cast crankshaft is carried on three Glacier bearings of white metal on steel, the steel being 0.065 in thick. Their inside diameters are all 2½ in, and the effective length of each of the front two is 1½ in, while that of the rear bearing is 2¼ in. The length of the crankshaft between the rear of the front journal bearing and the front of the rear one is 16½ in. Between adjacent pairs of crankpins, the projected length of the inclined crank arms is 2⅞ in; while the thickness of the vertical webs is $\frac{7}{8}$ in. Each crankpin is 2⅜ in diameter and 1⅜ in long.

End location is effected at the back, where the front and rear ends of the two half-bearing shells are furnished with $\frac{5}{16}$ in flanges. Immediately to the rear of the oil thrower, the shaft diameter is increased to 3½ in, and on it is machined an oil return scroll that runs in the flywheel housing. It is considered that the rubbing velocity here is too high for a tip-type seal.

Spigot-mounted on the rear of the crankshaft is the En 12 flywheel. It is secured by six bolts spaced around a lipped central recess from the outer periphery of which there are drilled passages to the front face of the flywheel. These ensure that no grease will pass to the clutch, should any escape from the ball bearing carrying the front end of the clutch shaft in the bored end of the crankshaft. In the illustration of the engine general arrangement, the starter gear is shown machined on the flywheel. However, in the latest engines it is a shrunk-on ring made of En 12.

H-section, En 12 connecting rods are employed. The big ends with their run-in white metal bearings are split at right angles to the axis of the rod, and the caps are secured by two $\frac{7}{16}$ in diameter En 16V bolts fitted with split-pinned, slotted nuts. A flat on the round heads of these bolts registers against a shoulder on the rod to prevent rotation. Location of the cap is effected simply by the fit of the bolt in its hole.

Splash lubrication of the pressed-in, Carobronze small-end bush is assisted by a drilling in the top end of the connecting rod. The inside and outside diameters of the hardened and ground hollow gudgeon pin are respectively ½ in and $\frac{7}{8}$ in. End location of the pin is effected by Seager circlips in the piston bosses. There is an effective bearing length of ¾ in inside each piston boss, while the length of the small end bush is 1 in.

The T-slotted, aluminium alloy pistons are supplied by the Automotive Engineering Co. Ltd., or by Wellworthy Piston Rings Ltd. In the pistons, two plain compression rings, having a face width of $\frac{3}{32}$ in, and one slotted scraper ring $\frac{5}{32}$ in wide, are positioned above the gudgeon pin. In addition, below the pin, there is one plain oil control ring, $\frac{5}{32}$ in wide in the Wellworthy pistons and $\frac{3}{16}$ in wide in the others.

Timing gear, camshafts and valve gear

At the front of the engine an extension of the crankshaft is machined down to 1½ in diameter to carry the En 18 chain sprocket, and then stepped down again to 1¼ in diameter for the stamped En 8 fan-belt pulley. Each is driven by a Woodruff key, and the whole assembly is held in position by a cap nut with a pegged extension for the starting handle. This nut is secured by a locking ring bolted to the front face of the pulley. A Super oil seal housed in the front cover bears on the pulley boss at the rear.

A cord-reinforced rubber fan-belt is employed. It has a V-angle of about 30 deg, a maximum width of ¾ in, and a thickness of ½ in. Both the driven pulleys are of cast aluminium. Housed in the forward-extended boss of the upper pulley are two ball bearings separated by a tubular distance-piece 1⅜ in long. These bearings carry the pulley on its En 5 spindle.

The outer race of the front bearing is about $\frac{3}{16}$ in proud of the end face of the boss, and on it is spigoted the four-bladed, pressed steel fan which

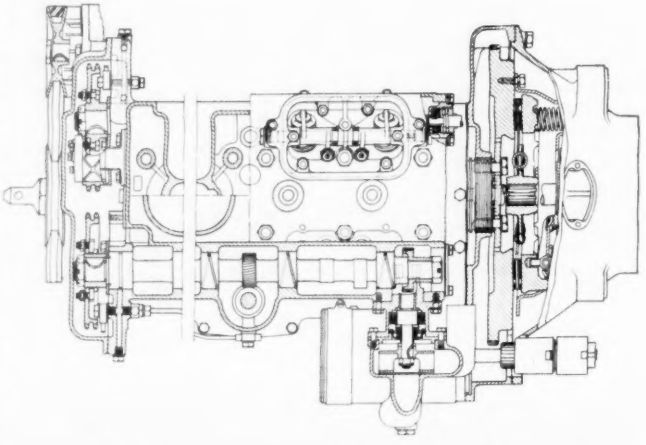


Fig. 6. Four rocker boxes are bolted on the cylinder head

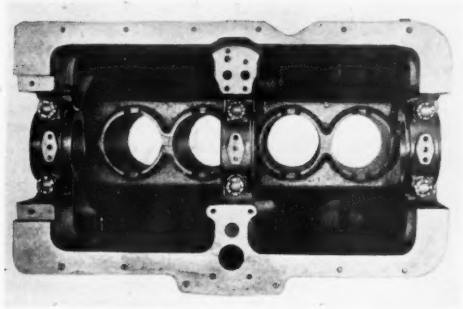


Fig. 5. Bosses are incorporated on the three main journal caps, for pressure oil pipe connections

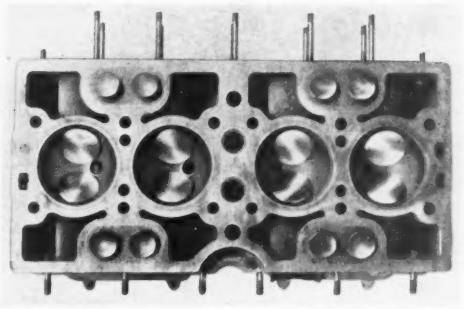


Fig. 10. The cylinder head, incorporating generous water passages, houses the tappets

is secured to the pulley boss by four $\frac{1}{4}$ in diameter bolts. Apart from the restriction against forward motion, imposed by the fan, this race is floating axially in its housing. Axial location of the assembly is effected by the outer race of the rear bearing. The front face of this bears against a shoulder in the boss, and against the rear face is a Seager circlip.

At the front, a $\frac{7}{16}$ in slotted nut pulls the whole assembly up against a shoulder on the spindle, the thrust being taken through the two inner races and the distance tube. At the front and rear bearings, the diameters of the spindle respectively are $\frac{1}{2}$ in and $\frac{5}{8}$ in. Immediately behind the rear bearing is a Super oil seal housed in the rear end of the boss. It bears directly on the spindle, the diameter of which is $\frac{7}{8}$ in at this position.

The $\frac{5}{8}$ in diameter rear end of the spindle is screwed into the front of the crankcase, a hexagon-shaped collar to take a spanner being machined on the spindle immediately in front of the timing cover. Additional support for the spindle is furnished by a boss, cast integrally with the timing cover front wall. The hexagon collar is tightened against this boss which is extended to the rear to bear against the crankcase. No locking device is required as the direction of rotation of the fan is such that it tends to screw the spindle into the crankcase. A hole is drilled in the top of the boss in the timing cover. It passes oil, splashed off the timing wheels, to an annular groove around the spindle which, at this point, is $\frac{23}{32}$ in diameter. From the groove the oil passes through drillings carrying it along the spindle and out between the two ball bearings. The inlet hole in the boss is, of course, higher than the outlet in the spindle.

Inside the timing cover a two-row roller chain, of $\frac{3}{8}$ in pitch, drives the two half-speed wheels. On the right-hand side, engaging on the outer run of the chain drive, is a tensioner. This is an eccentrically mounted jockey-sprocket bolted to the front of the crankcase. Adjustment can be made to the tension in the chain without removing the timing cover. On the other side of the crankcase is a Tufnol block bolted on the front wall to prevent excessive whip of the chain which it just clears in the static position.

Each half-speed wheel is secured to the front of its flanged hub by four $\frac{1}{4}$ in bolts and nuts locked with spring washers. The bolts are in holes slotted to permit a certain amount of rotational adjustment. Location against rotation relative to the hub is effected by two eccentric dowels positioned on the same pitch circle as the bolts, but diametrically opposite one another. These resemble bolts with an eccentric round head, and with a screwdriver slot in the end of the shank. Each is secured to the half-speed wheel, by a nut and a spring washer, with the eccentric head at the rear registering in a radial slot machined in the outer periphery of the hub. It is, therefore, possible to remove the wheel from its hub without disturbing the setting of the timing. The eccentric gives 10 deg adjustment, which is more than the angular spacing of the 44 teeth of the sprocket, so there is, in theory, no limit to the possible accuracy of the setting.

VALVE SPRING DATA

	Inner	Outer
Free length	1·718 in	2·437 in
Installed length	1·050 in	1·562 in
Spring rate	68·5 lb/in	63·0 lb/in
Outside diameter	0·910 in	1·187 in
Wire gauge	0·110 in	0·135 in

On the front end of the Monikrom alloy cast iron camshaft, a split-pinned, slotted nut pulls the half-speed wheel, driven by a Woodruff key, against a shoulder. Around the shoulder is a hardened and ground, mild steel plate, bolted to the front wall of the crankcase. It is positioned between the boss of the half-speed wheel and the forward face of the front camshaft journal.

The diameter of this journal is $1\frac{3}{4}$ in, and that of the rear one is $1\frac{11}{16}$ in. All the journals, except the front one, are $\frac{7}{8}$ in long and have spiral grooves machined in their periphery to assist lubrication. The front journal is $1\frac{3}{16}$ in long and has an annular groove around it. Unlike the others, it is fed with oil under pressure. The cam profiles are of the three-arc form, except that a quietening ramp is incorporated.

Machined on the camshaft on the exhaust side, approximately mid-way between its two ends, is a spiral gear to drive the vertical spindle for the oil pump, and ignition contact breaker and distributor. Keyed on a $\frac{3}{4}$ in diameter rearward extension of the camshaft is the En 32 spiral gear driving the water pump. This gear is pulled up against a shoulder on the shaft by a split-pinned, slotted nut.

Chilled cast iron tappets are employed, and they are housed in the cylinder head at an angle of 15 deg from the vertical in the transverse plane. Their axes are offset $1\frac{3}{16}$ in from those of the valves, measured parallel to the rocker spindle. Pressed in the ends of the tappets are En 32 steel cup-fittings in which seat the ball-ends of the push rods, also of En 32. The push rods are stampings with an effective length of $2\frac{9}{16}$ in. Their cup-shaped upper ends and their lower ends are not up-set, but are machined.

The rockers are En 32 stampings, case-hardened all over. Pads at their outer extremities bear on top of the valve stems while, at their inner ends, there are $\frac{5}{16}$ in diameter ball-ended tappet adjusting screws and lock nuts. The rocker ratio is 1·393 : 1. Each of the four spindles, $6\frac{3}{8}$ in long by $\frac{9}{16}$ in diameter, carries a pair of rockers. These four assemblies are each housed in a cast aluminium box, on the walls of which are lugs for four $\frac{1}{4}$ in diameter bolts securing it to the head. A boss in each end wall of the box, and another, in a central web extended inwards from the outer side-wall, are bored to carry the spindle. Hexagon-headed plugs are screwed into the outer ends of the bosses in the walls, and dowel-ended bolts, $\frac{5}{16}$ in diameter, are screwed into the top of them to register in radial holes drilled in the spindle to locate it. Machined integrally with the head of each of these bolts is an upward-projecting stud, also $\frac{5}{16}$ in diameter, on which is a self-locking nut securing a cast aluminium cover on top of the box. A similar bolt passes through the central web to secure it firmly to the cylinder head. In the two front boxes the upper extension of this central bolt carries a knurled nut securing the oil filler cap, and on the two rear ones is a self-locking nut helping to hold down the cover. The joint face between the cover and the box, as well as that between the box and the head, is sealed with an Oakenstrong washer. Around the spindle on each side of the centre web is a compression spring to constrain the rockers against the bosses on the end walls.

Two concentric springs around each valve stem, bear at their lower ends in a recess in the cylinder head, and at their upper ends against a washer secured by split collets, rubber faced at the abutment to prevent oil running down the valve stems. The inner and outer springs are coiled in opposite directions to obviate the possibility of interlocking. Springs for the inlet valves, and those for the exhaust valves are identical.

The inlet valves are of En 53 while the exhaust valves are made of En 54. All valve guides are of cast iron and are interchangeable. Their lower ends are chamfered externally, for $\frac{3}{32}$ in at an angle of 15 deg. The wall thickness of the guides is about $\frac{1}{8}$ in. The seats for the valves are all cut in the cylinder head. In order that valve timing may be checked without removing the rocker covers, there is opposite each valve a drilled and tapped boss on the side of the rocker box and normally sealed with a hexagon-headed plug. The plug can be removed and a rod inserted to indicate the opening and closing of the valve.

VALVE AND TIMING DATA

	Inlet	Exhaust
Head diameter	1·75 in	1·59 in
Throat diameter	1·59 in	1·437 in
Stem diameter	0·312 in	0·312 in
Lift	0·378 in	0·378 in
Valve opens	15 deg B.T.D.C.	55 deg B.B.D.C.
Valve closes	55 deg A.B.D.C.	15 deg A.T.D.C.
Tappet clearance	0·010 in	0·012 in
Ignition advanced	18–22 deg B.T.D.C.	
Ignition retarded	T.D.C.	

Cylinder head and manifolds

Twelve $\frac{7}{16}$ in diameter studs made of En 16V secure the cast iron cylinder head to the block. The head is $3\frac{5}{16}$ in deep and, because of the valve gear layout, its width is $8\frac{3}{4}$ in overall. As a result, the valve ports are rather long. However, they are well cooled by generously proportioned water jackets. Very large ducts are furnished to ensure free passage of coolant between the head and the block. A copper and asbestos gasket is fitted at the lower face, and the whole of the top face of the cylinder head is machined to carry the rocket boxes and the make-up piece for the front cover. Also bolted to the top of the head is the water outlet, the inlet being secured in a similar manner to a machined face on the rear end.

Recessed more than $1\frac{1}{4}$ in into the top of the head are the four bosses for the vertically positioned 14 mm spark plugs. The axis of each plug is positioned $\frac{11}{16}$ in to the rear of the transverse plane containing the axes of the valves of the same cylinder. With this arrangement, the largest possible valve head and port area is obtained. Hemispherical combustion chambers are incorporated in the cylinder head to give the lowest ratio of volume to surface area that is possible with a flat-topped or domed piston.

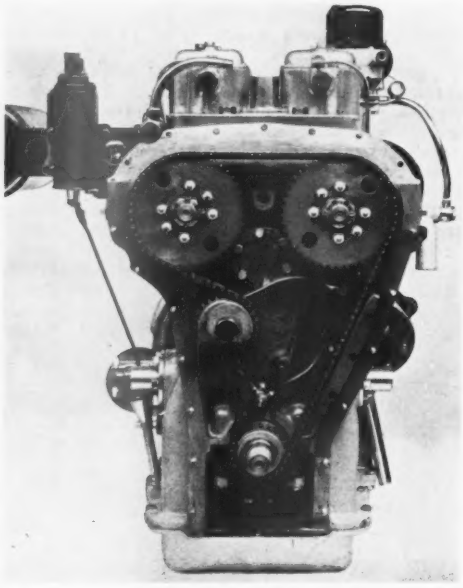


Fig. 8. An eccentrically mounted jockey sprocket may be adjusted to vary the timing chain tension

At the top of each of the two Y-shaped exhaust manifolds, made of cast iron, the flanges for the $\frac{5}{16}$ in diameter studs are joined together by an integral bridgepiece. Thus, only three studs are needed to secure each pair of manifold branch pipes to the head. Another flange at the lower end of each manifold is bolted to the Y-shaped end of the exhaust pipe.

The inlet manifold is formed partly in the head and partly by the aluminium casting extending almost the whole length of the head. Along the top of this casting is a cored water jacket, at each end of which is a union. The by-pass circuit, from the thermostat valve in the outlet pipe, passes through the jacket to the inlet side of the water pump. Thus, hot water is circulated as soon as possible when starting from cold. In the pipe between the union at the rear of the jacket and the pump inlet is a T-adaptor for the car heater. On the 18 h.p. engine, one H.6. type S.U. carburettor, with a $1\frac{3}{4}$ in diameter choke, is bolted on midway along the manifold, whereas twin H.3. carburettors, of the same make but with $1\frac{3}{8}$ in diameter chokes

are employed on the 2½-litre sports version. Fitted to the saloon model is a large Vokes air cleaner and silencer, supported by two pressed steel brackets bolted to the manifold. On the sports engine two Vokes flat type cleaners are used.

Water pump and cooling system

The En 4 spindle for the water pump is mounted horizontally, with its axis at right angles to, and 1·464 in below the axis of the left-hand camshaft. It is carried in two phosphor bronze bushes, each flanged at its outer end. One of these bushes is housed in the inner side wall of the camshaft cell, and it carries the ½ in diameter end of the spindle. The flange on this bush forms a thrust bearing for the En 32 spiral gear, which is restrained from moving in the other direction by a shoulder on the spindle. The gear has a helix angle 45 deg, and it drives the pump at 1·9 times camshaft speed. The second bush is pressed into a boss on the cast aluminium pump cover bolted to the camshaft cell. A drilled hole through both the top of the boss and the bush assists splash lubrication. Bearing on the flange of this bush is a shoulder formed by a 1 in diameter collar machined on the spindle. Around the periphery of this collar, which is chrome faced, is a Super oil seal housed in the pump body.

A spring-loaded water seal, of moulded rubber, with a carbon thrust ring insert, is carried in the cast aluminium pump cover. The seal is supplied by Super Oil Seals and Gaskets Ltd. Its carbon ring bears against a cast iron thrust washer. This washer is held against the collar on the spindle by a distance tube passing through the seal. Pulled against the other end of this tube by a split-pinned, slotted nut on the end of the spindle, is the fully shrouded pump rotor. This is a die casting, 2⅝ in diameter, made of corrosion-resistant aluminium alloy. An adaptor for the by-pass pipe from the thermostat is fitted to the pump inlet. Screwed into bosses on the joint face of the pump body are six ¼ in diameter studs. These secure it to the pump cover. A drain cock is fitted at the lowest part of the body.

In the sports car a fin-and-tube radiator of 1·4 ft² frontal area is employed, while that in the saloon version has an area of 1·9 ft² Water is drawn by the pump from the base tank of the fin-and-tube radiator. It is then discharged into the cylinder head, on the rear rear end of which is bolted an inlet elbow. The outlet pipe is at the front, on top of the head, and it passes the water back through the thermostat to the header tank. As mentioned before, the by-pass from the thermostat passes through the manifold jacket to the pump inlet. The water capacity of the whole system is 25 pints. The cylinder walls are cooled by a subsidiary thermo-syphon action through large ducts between the head and cylinder block jackets. Although the rear position of the pump entails a rather long pipe from the radiator base tank, it does give certain advantages. If the pump had been placed in the conventional position in front, mounting would have been difficult owing to the high position of the half-speed wheels. Furthermore, the overall length of the engine would have been increased, and the passage of water from the pump to the block would have been complicated. The arrangement adopted gives a good through flow of water from end to end of the head.

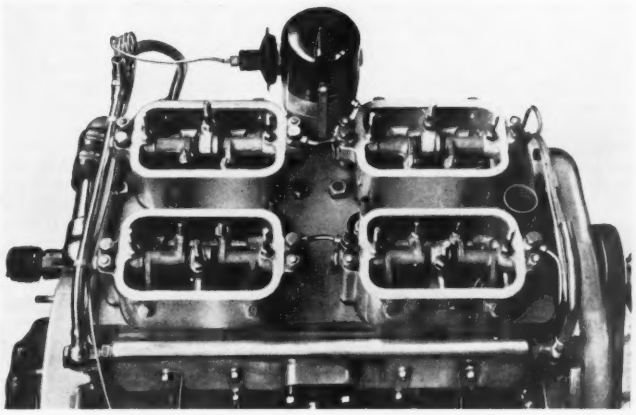


Fig. 9. Screw plugs in bosses on the rocker boxes may be removed to determine valve settings, without removing the rocker covers

Oil pump and drive

A phosphor bronze spiral gear driving the oil pump and ignition contact breaker and distributor, meshes with the gear machined on the exhaust camshaft approximately midway between its ends. It is keyed to a case-hardened En 32 spindle, ⅜ in diameter and 6⅛ in long, which is driven at camshaft speed. This spindle is carried vertically, and is supported at its lower end in a phosphor bronze bush pressed into a boss in an extension of the lower wall of the camshaft cell. Above, the spindle is further supported in a phosphor bronze boss.

A flange around this boss is clamped between the top face of the cylinder block and a flange at the lower end of a cast aluminium, tubular adaptor for the ignition contact breaker and distributor unit. A Super oil seal is housed in the aluminium adaptor and bears on the spindle which, at the top end, is drilled axially, and slotted to engage the tongued driving sleeve of the contact breaker and distributor.

Machined approximately half way between the ends of the spindle is a collar. Its lowest face bears on the flanged upper end of the lower bush while its upper face seats in a recess in the gear. The direction of rotation of the camshaft gear, with its helix angle of 45 deg, is such as to impart to the driven gear a downward thrust which is taken through the collar on the spindle to the flanged bush. Upward movement of the gear is restricted by the boss above it. The bush at the lower end is fed with oil under pressure. A slot, machined in the spindle, carries the oil inside the gear boss and upwards to lubricate the upper phosphor bronze boss. Holes, ⅛ in diameter, are drilled through the flange to return the oil to the cell.

Machined in the lower end of the spindle is a slot to engage the ⅝ in by ¼ in rectangular section, En 5 vertical driving member for the oil pump. This member is located in its slot by a steel sleeve, ⅝ in inside diameter, pressed on to the spindle. A similar arrangement is employed to locate the lower end which is 12⅛ in from the upper end, but the sleeve is split-pinned on the slotted pump spindle so that both driving member and sleeve may be removed without first lowering the oil pump.

The vertical driving member enters the crankcase through a boss about 7 in below the camshaft cell. Around it is a 12 S.W.G. steel tube located at its lower end by a bolt screwed radially into the boss. At the top end, the tube is carried on an extension of the phosphor bronze bush around the

upper driving spindle. The top end of the tube bears against the flat lower face of a steel washer which is, on its upper face, internally chamfered to seat a toroidal rubber sealing ring bearing against the lower face of the camshaft cell. Pressed in the tube, about $1\frac{1}{2}$ in below its top end, is an internally chamfered guide ring to assist in the assembly from below of the driving member into its slot.

A gear type oil pump is employed. It is bolted to a boss on the lower face of the crankcase so that it is partially submerged in the cast aluminium sump which has a capacity of $12\frac{1}{2}$ pints. The body of the pump is of cast-iron, and its bottom cover is of gun metal. Both the driving and the driven gear spindles are supported at their lower ends in bearings formed by the cover. The upper end of the En 32 driven spindle is shouldered and is threaded for a split-pinned, slotted nut securing it to the top of the pump body. To clear this nut, the lower face of the boss on which the pump is mounted in the crankcase, is drilled $\frac{11}{16}$ in diameter. Around the spindle is a phosphor bronze bush forming the bearing for the driven gear.

The driving gear is keyed on its En 33 spindle, the upper end of which is supported in a phosphor bronze bush in a boss in the pump body. At the lower end of this bush is a flange which is recessed into the lower face of the boss. A $1\frac{3}{16}$ in diameter hole is drilled in the crankcase to locate this boss, the outer periphery of which is machined. Both gears are made of En 8. Apart from the driving gear, the top face of which bears against the flanged bush, both are located axially between the bottom cover and the body. Axial location of the spindle is effected by the driving member at its top end, and by a shoulder, about half-way down, which bears on the top face of the gear.

An unusual feature of the lubrication system is that most components are fed with oil through pipes. The lubricant is drawn by the pump through a strainer, mounted between two pressed steel baffles on the centre of the floor of the sump, and then through a short pipe to the pump inlet. From the outlet, is passes through pipes to a boss on the lower face of the right-hand wall of the crankcase. Drillings take the oil past an adjustable relief valve, set to lift at about 30 lb in^2, to a Tecalemit full-flow filter.

The return from the filter is through drilled ducts to the lower face of the crankcase. From here the oil is piped to a four-way union under the centre main journal. It is then piped to annular grooves around each main journal. Drillings in the crankshaft feed the big ends, and the small ends are splash lubricated.

Ducts carry oil from the annular groove around the front journal bearing to a union on the front wall of the crankcase. On the front of the union is a metering jet to drip oil on the timing chain sprocket. Two pipes connect this union to two others, on the front wall of the crankcase, $1\frac{1}{4}$ in to the outer side of each camshaft axis. From a T-junction on the left-hand pipe, oil is carried across the front face of the crankcase to the chain tensioner sprocket. From each of the two unions, a duct is drilled through the wall which, at this point, is extended laterally to form a flange on the side of the engine so that the rear face is outside the crankcase. A transverse drilling in the wall connects the longitudinal duct with the front camshaft bearing. The remainder of the bearings and working faces of the camshafts are lubricated by oil, the level of which is maintained about $\frac{1}{4}$ in below the axes of the camshafts in the cells.

A union, screwed into the duct at the rear face on the left-hand side, has two pipes connected to it, while that on the right has only one. On the left, the extra pipe serves the bush for the oil pump, and contact breaker and distributor drive spindle. The other two pipes, one on each side, are connected to the front rocker boxes.

Through the rocker gear, the circuit is as follows: Oil passes into the union on top of the boss on the front wall of the front rocker box, and down through a duct to the space between the end of the rocker spindle and the sealing plug in the outer end of the boss. Along the length of the spindle is an axial drilling, $\frac{3}{16}$ in diameter along which the oil passes to a space in the boss between the rear end of the spindle and the sealing plug. A vertical duct connects this space with a union on top of the boss, and a short pipe carries the oil to a similar union on the front boss of the rear rocker box. The passages in the rear box are identical with those in the front except that a screwed in plug seals the rear of the drilled spindle. Radial drillings feed each rocker bearing, and a duct in the rocker arm supplies oil to an annular groove around the tappet adjusting screw which is drilled so that the seating face, on the top end of the push rod, is positively lubricated.

On each side, a duct in the cylinder head interconnects the two rocker boxes. The main oil return is into this duct, and down a vertical one communicating with the camshaft cell. A certain amount also leaks past the tappets, lubricating them at the same time. The overflow from the camshaft cell is at the front. From here it drains down to the sump.

WEBSLIGHT REFLECTORS

REPORTS issued by the Traffic and Safety Division of the Road Research Laboratory and by the Standing Joint Committee of the R.A.C., A.A., and R.S.A.C. have stressed the urgent need for better rear lighting and more adequate rear marking to improve vehicle identification at night.

Webslight reflectors, which conform to existing Continental systems for static and mobile signs, are designed to meet such specifications. They consist of thousands of minute, spherical glass beads embedded in layers of transparent lacquer.

Certain technical problems were encountered in production. The aluminium alloy base plates, deemed essential to obviate rust and deterioration, must be thoroughly degreased and the surface chemically treated and primed to obtain perfect adhesion of the pigments and lacquers. The pigment must be carefully specified to retain its colour consistency under daylight and in the yellow-light conditions produced by vehicle headlamps. Infra-red heating was tried initially for the stoving of individual layers of lacquer but gave too rapid a rate of drying and resulted in brittleness. The controlled, hot-air system of drying now used ensures complete polymerization with a plastic finish.

The small glass beads, termed "ballotini," that serve as a reflecting medium, are true spheres produced by a tumbling process and subsequently screened for size. Two sizes are used. The smaller having a diameter of 0·05 mm is used for narrow-angled reflectors and gives up to 40 deg divergence, while the 0·08 mm size returns the light at angles up to about 80 deg. Angular reflection from a given sign is arranged as a compromise between maximum light value in alignment and maximum deflection for close identification. A reduction in the deflection angle will give increased range to the returned light but necessarily lessens the "near-sight" factor.

Produced by the Cheshire Engineering Co., Ltd., Burwood House, Caxton Street, London, S.W.1, the reflectors can be bent to suit the contour of a vehicle panel and can be drilled or cut without chipping or flaking. (2018)

ENGINE MANUFACTURE

Recent Production Developments at the Works of Vauxhall Motors Ltd.

TWO new engines, a four-cylinder and a six-cylinder, have been developed by Vauxhall Motors Ltd., Luton, for their Wyvern and Velox cars. In passing, it may also be noted that the four-cylinder engine is also used as the power unit for a new light delivery van. Both engines are "better than square" type, with a 3¼ in diameter bore and a 3 in stroke. The design features of these engines will be fully discussed in a subsequent issue of this journal; these notes are concerned only with the production methods that have been adopted to produce, as economically as possible, engines with a uniformly high standard of performance. A part sectioned view of an engine is shown in Fig. 1.

So far as engine design is concerned, only one or two points need be mentioned here. The first is that the maximum possible use is made of components common to both engines. For example, identical pistons and connecting rods are used. Secondly, when the components must necessarily differ, the cylinder block is the obvious example, throughout all stages of development the closest liaison was maintained between the design and production engineers to ensure that in the maximum possible degree, the machines and the tooling would be suitable for either six-cylinder or four-cylinder parts.

General layout

All the detail machining and assembly functions for the manufacture of these new power units are concentrated in the new factory opened by Vauxhall Motors Ltd. early in 1951. This factory also houses the production sections for Bedford truck engines and gearboxes, and the final assembly line for trucks. Only a very limited floor area was available for passenger car engine manufacture. At the outset this space limitation may have appeared to be a drawback, and it certainly posed some difficult layout problems. It has, however, probably proved to be an advantage, since it imposed the necessity of developing an extremely compact layout that makes remarkably efficient use of the superficial area.

The area that is used solely for the production of passenger car engine details and the assembly of the engines is rectangular. Assembly is carried out on a special conveyor that runs down one side of the rectangle. Machining lines for all the major components run transversely across the width of the rectangle. They are so arranged that on every line the machining ends in a position adjacent to the appropriate station on the assembly conveyor. This, of course, reduces the amount of material handling that is necessary.

In a considerable degree, the machine layout has been governed by the manufacturing policy that has been adopted. With regard to the machining of components that are not common to both engines, there are two ways of approaching this problem. It is possible to lay out a line in which every machine can be adapted for use on either four- or six-cylinder parts. It has not, however, been found practical to so design engines that every machine operation on, for example, a four-cylinder and a six-cylinder block, can be carried out without any tool changing. Consequently, if a single line is used for all operations, cylinder blocks must be machined in batches.

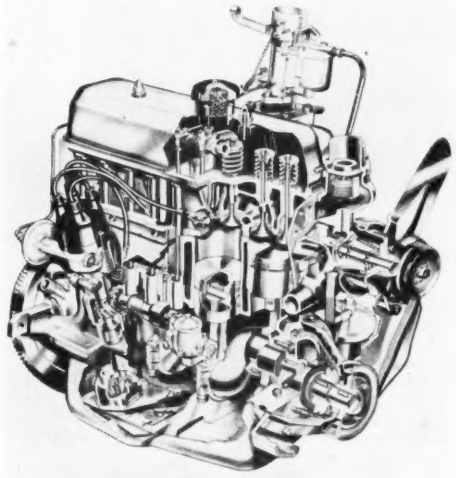


Fig. 1. The new square engine for Vauxhall "Wyvern" cars

Vauxhall Motors Ltd. have preferred the alternative policy. Where it is impossible to use the same tooling set-up for both engines, two machines are installed, one tooled for four-cylinder and the other for six-cylinder work. This calls for a slightly more complex routeing of the work through the machine line. It also entails additional capital outlay for machines. To set against these factors, there are counter-vailing advantages. The chief one is undoubtedly the much greater production flexibility that comes from being able to machine either size in any desired order. In addition, idle machine time for tool changing is reduced, since changes are made only when tool deterioration makes them necessary and not at the end of every batch. Furthermore, this system of production probably entails a smaller stock of work in progress since it removes the need for contingency stocks to meet sudden changes in demand. Finally, the use of separate machines at certain stations helps to maintain a balanced machine cycle.

This system of having four- and six-cylinder parts progressing together through a machining sequence almost inevitably ruled out the possibility of using multi-station transfer machines. Instead, extensive use has been made of machines with a number of heads to carry out several operations at one station. In developing this section, the engineers of Vauxhall Motors Ltd. have received close co-operation from machine tool manufacturers, particularly of James Archdale and Co. Ltd., William Asquith Ltd. and Cincinnati Milling Machines Ltd. One of the chief terms of reference was that the machines should be designed to reduce handling to the minimum.

There is a completely separate section for the production of complete gearbox units. In this section, both passenger car and truck units are machined and assembled. Transfer of passenger car units to the engine assembly line is effected on an overhead conveyor. Certain other engine components are machined outside the passenger car engine area. These are all relatively light and easily handled components which are transported in unit loads by trucking to the appropriate assembly station.

Cylinder block machining

By far the most complex layout is that for the cylinder block machine lines. The length available is far from sufficient to allow machining to be carried out along one straight line. As a result it has been necessary to loop this line several times. Further com-

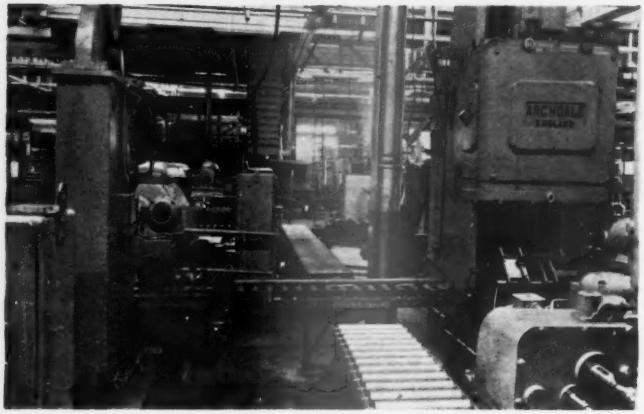


Fig. 2. Part of the cylinder block line, showing a turntable in the roller track for feeding to right and to left

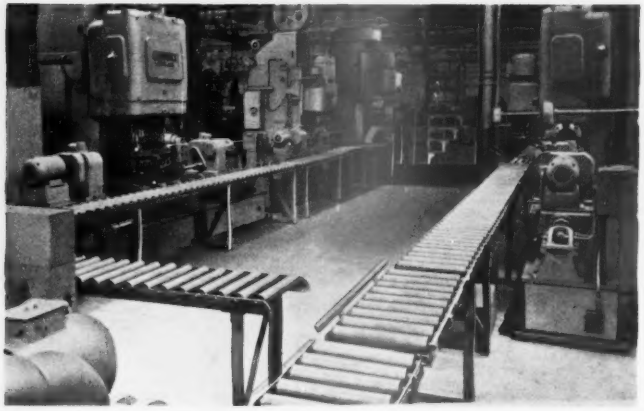


Fig. 3. A section of the cylinder block line with separate tracks for four- and for six-cylinder blocks

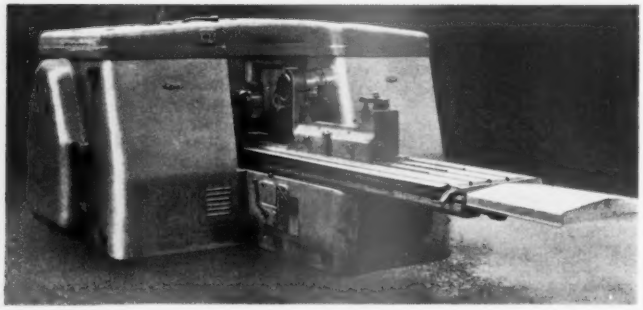


Fig. 4. A special six-spindle heavy duty Cincinnati milling machine for machining the sump and joint faces and the bearing cap seats

plexity arises from the need to have separate machines for each type of block at certain stations. Where this is necessary two lines are formed to converge later to form a single line.

An integral cylinder block and crankcase casting is employed. It is cast in Chromidium alloy by Midland Motor Cylinders Ltd. A very high standard of dimensional accuracy as cast is specified and maintained. As a result it has been possible to eliminate any preliminary machining merely to obtain register points for subsequent operations.

Castings pass from one machine to the next on a roller track 32 in above floor level. All the machines are arranged to load and unload at this height. Where it is necessary to have separate machines for four-cylinder and another for six-cylinder blocks, these machines are arranged to the left and to the right of the roller track from which they are fed. A section of the track is free to revolve through 360 deg to allow the work to be diverted right or left as required. If the divergence is only for one operation and end loading is possible, the machines are set at right angles to the normal line of flow, see Fig. 2. Incidentally, this arrangement has been adopted at one or two stages where both machines are used for both sizes of blocks; this has been done to make the most effective use of the floor area. When two or more machines are successively on only one size of block, the roller track divides into two branches with the work progressing in a straight line along each branch, see Fig. 3.

The first machining operation on the cylinder block is carried out on a Cincinnati special heavy-duty, low-bed six-spindle milling machine. There is one machine for four- and another for six-cylinder blocks. One machine is illustrated in Fig. 4. The machines themselves are identical. At this operation two cutters in one head rough and semi-finish the head face to leave 0·030 in to be removed at a much later operation, while at the same time four cutters in the other head rough and finish the sump face and rough the bearing cap seats for depth and width. These seats are finished at a later broaching operation. The milling at the first operation leaves 0·015 in on depth and 0·030 in on width.

The casting is loaded into the work fixture with the welch plug side down and the front end leading. Location in the fixture is taken from pads and a vee cast on the side of the block. These milling machines have been specially designed to give very high rate of metal removal at high speeds and feeds. The surface cutting speed is in the order of 200/250 ft per minute for roughing and 300/350 ft per minute for finishing; the feed rate is 50 in per minute. Special Galtona cutters with many more and much thinner tungsten-carbide tipped blades than are used in normal practice have been developed to allow these high speeds and feeds to be employed successfully.

For roughing and finishing the head face there are two cutters, each 7 in effective diameter and having 28 blades. Two cutters are used for roughing the sump face. Each is 8¾ in effective diameter and has 34 blades. The sump face is finished by a 54 blade cutter of 16 in effective diameter. A 5 in diameter end milling cutter with 16 blades is used for machining the bearing cap seats. This cutter is mounted to follow closely after the roughing cutters. Because of the high number of blades in the various cutters the tooth loading, even at the high speeds and feeds employed, is favourable. It varies from 0·008 in to 0·013 in. Here it may be pointed out that the machining conditions quoted are also used at subsequent main milling operations.

So far as accuracy and quality of surface finish are concerned, the joint face could also be finished at this first operation, but for two reasons Vauxhall Motors Ltd. consider that the final machining on this face should be carried out as late as possible in the operation sequence. First, there is the danger of accidental damage to the face during the passage of the block through the machine cycle. Second, there is a possibility that the machining processes may release casting stresses and cause slight distortion.

After the first milling operation, the casting is transferred to the roller track with the sump face uppermost and the front end leading in the case of the six-cylinder block and the rear end leading in the case of a four-cylinder block. There are two tracks which diverge to bring the casting to the appropriate machine for the next operation.

There are two Archdale three-way multi-spindle drilling machines for the second operation. They differ only in the number of tools mounted. This also applies with one exception to the other stations where there are separate machines for each type of block. The exception will be noted in due course. These notes are based on the machining of the six-cylinder block, and reference to the four-cylinder sequence will be made only when there is a difference other than in the number of tools employed.

The Archdale machine for the second operation, which is shown in Fig. 5, has a vertical head, a horizontal head at the rear and another horizontal head at the front of the track. Through loading is employed. Height location for this operation is taken from the sump face, transverse location from the bearing cap seats, and length location from a vee projection on the side of the casting. This vee is cast in accurate location to the cylinder bores.

There are 33 spindles in the vertical head. Combination tools for drilling and reaming are mounted on two. These are used for drilling and reaming two holes in the sump face that are used as locations at all subsequent operations. The other spindles drill 22 oil pan holes in the sump face, eight bearing cap bolt holes and one oil hole which at this stage is only drilled to half depth. Five welch plug holes are core drilled from the front head and two holes are drilled and one hole core drilled from the rear head. Here it may be remarked that great use is made of straight shank drills with drivers instead of drills with taper shanks. This, particularly for small diameter drills, has proved an economy.

Quick - action, manually - operated wedge type clamping is employed on this Archdale machine. In fact, manually-operated clamps are widely used throughout the whole machining sequence. In every case the clamping mechanism is such as to call for surprisingly little physical effort to give perfectly secure clamping. Furthermore, all the clamping is effected rapidly. It may also be pointed out that at every machine the locating and clamping devices are so interconnected with each other and with the machine drive, that until correct location has been obtained the clamps cannot be applied and until the clamps have been applied the machine cycle cannot be started. The reverse sequence also holds good when the machine cycle is finished.

At this stage the two roller tracks converge to form a common track. When the casting reaches the common track, but before it is loaded into the next machine, all the holes in the sump face are countersunk by means of an air drill suspended on a balancer above the track. This is general practice throughout the machining sequence.

The casting is turned on to the sump face with the rear end leading for the next operation which is carried out on a special Archdale milling machine with a planetary head and an angular travelling head. The machining at the two previous operations has produced machined surfaces to give accurate

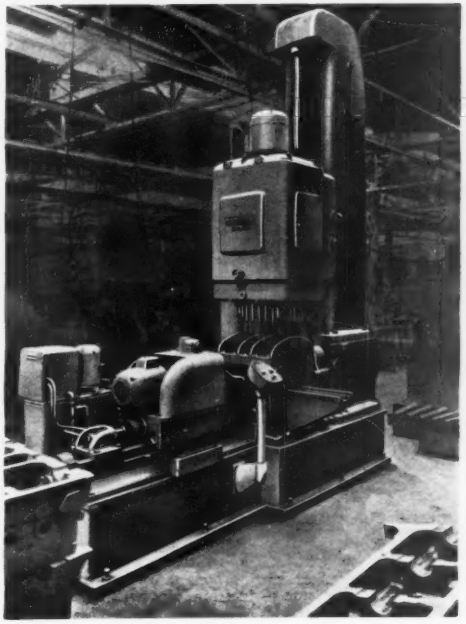


Fig. 5. Archdale three-way multi-spindle machine for the first drilling operations on the cylinder block

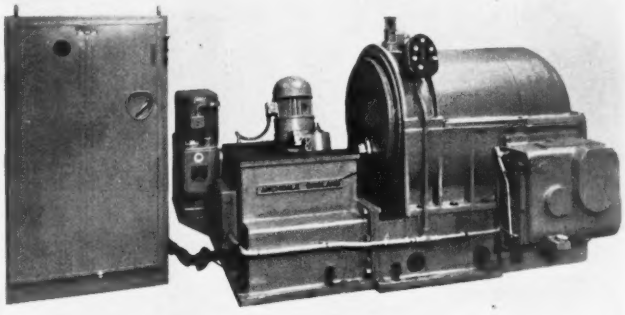


Fig. 6. A combination of a planetary head for milling the rear end of the crankcase and an angular travelling head for milling the bottom of the distributor boss

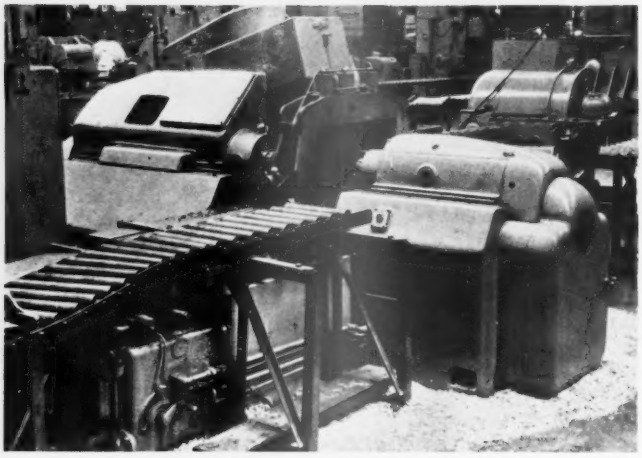


Fig. 7. Cincinnati special five-spindle duplex miller

register in all directions. Height location may be taken from either the sump face or the head face, but is invariably taken from the sump face, and transverse and longitudinal locations are given by the register of locating pins in the holes reamed in the sump face. Since these locations are used at all subsequent operations, further references to locations will only occasionally be necessary.

As this third operation is the first to be carried out on a machine that is common to both blocks, it may be as well to point out that on all common machines there are two levers for advancing and retracting locating dowels. There are three of these dowels in the fixture. One lever operates the outer dowels for locating a six-cylinder block; the other operates only the middle dowel but all three dowels must be raised before the machine cycle can be initiated on four-cylinder blocks.

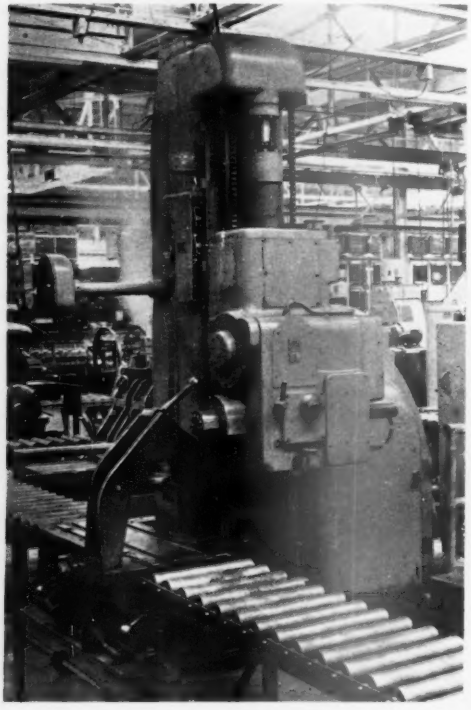


Fig. 8. Special Archdale plunge cut miller with a very simple type of work fixture

On this special Archdale milling machine, see Fig. 6, the planetary head is used for rough machining the rear end of the crankcase to leave $\frac{1}{32}$ in to be removed at a subsequent operation. A 20-blade, 8 in effective diameter cutter is used. At the same time, a face milling cutter mounted in the angular travelling head machines the bottom end of the distributor boss.

For the next operation the casting is turned through 90 deg on a turntable so that the front end leads. This operation is carried out on a Cincinnati special five-spindle, low bed, duplex Hydromatic milling machine. As on the other Cincinnati machines hydraulic clamping is employed. Five end mills are mounted on this machine, four on the rear head and one on the front. They mill the tappet cover face, the distributor face and number pad, the oil filter pad and two coil mounting bosses. The machine is shown in Fig. 7.

At the next operation the wiper drive face is machined on an Archdale special plunge cut milling machine. This machine, which is illustrated in Fig. 8, has a milling head mounted on a standard vertical drilling machine frame. The mechanism in the milling head is that of a standard milling head, and only the casing is special. Here it may be pointed out that although many of the Archdale machines are described as "special," they are, in fact, built up from standard units and are special only in the manner in which the units are combined.

Of this plunge cut miller, a 3 in diameter Galtona end milling cutter with eight tungsten-carbide tipped blades is used. The machine is arranged for through loading, and as may be seen from Fig. 8, a particularly open type of fixture is used. Essentially, the fixture comprises only a base plate to give register from the sump face and the two reamed holes, and a simple cam-operated clamping device.

The casting is then transferred to an Archdale three-way special multi-drilling machine. This machine has a vertical head tooled for drilling 14 cylinder head bolt holes in the joint face; a rear horizontal head for drilling three holes and combined drilling and reaming two dowel holes and a spindle for core drilling the rear end clean out hole; the other horizontal head, which is at the left, is tooled for drilling 19 holes in the tappet cover side of the block.

A Cincinnati special heavy-duty, two-spindle, low bed Hydromatic milling machine is used for the next operation. It is tooled for finish machining two faces at the front end of the crankcase by means of a 26 blade $7\frac{1}{4}$ in effective diameter and a 34 blade 9 in effective diameter cutter. Hydraulic clamping is used.

At this stage, although the next two operations are carried out on machines that are common for both blocks, the machines are arranged one on either side of the track in a position for end loading. For convenience in loading these machines, there is a turntable in the track on which the casting can be switched to the right or to the left. This arrangement has been adopted to give the best possible utilization of floor area.

An Archdale special three-way drilling machine is used. The casting is loaded with the joint face up and the front end leading. From the vertical head of this machine, 24 water circulation holes are drilled. A rear horizontal

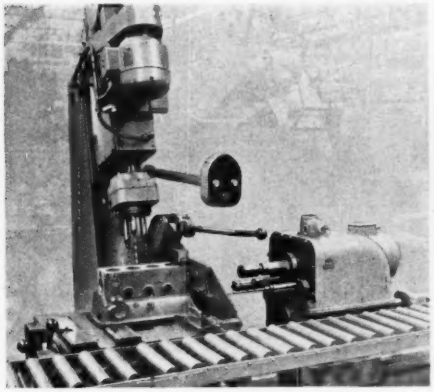


Fig. 9. An Archdale two-way machine with an angular vertical head for drilling three holes in the manifold side and a horizontal head for counterboring two holes and part drilling the oil gallery hole

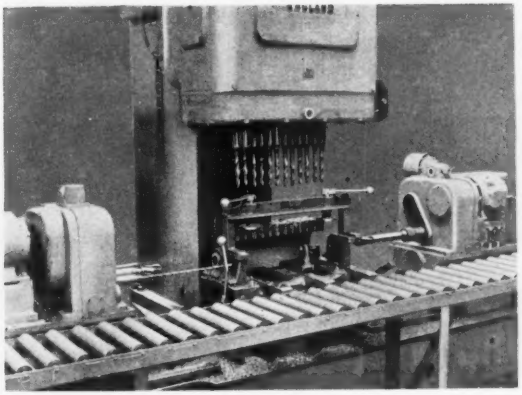


Fig. 10. A three-way machine. The vertical head drills the tappet holes; the left-hand head part drills the oil gallery hole and counterbores the front cam bearing; the right-hand head counterbores the rear intermediate cam bearing

head is tooled for drilling eight tapping holes and for core drilling the clean out boss in the front end of the block. A second horizontal head, at the right, has only a single spindle for drilling a $1\frac{5}{16}$ in diameter hole in the manifold side of the casting.

The casting is then pushed straight across to the second machine with the rear end leading. Another Archdale three-way drilling machine is used. It has a single spindle angular vertical head for drilling the top half of the distributor to leave an allowance for fine boring at a subsequent operation; a horizontal head at the rear for spot-facing the oil gallery hole, reaming the rear clean out hole and core drilling the rear cam bearing; a right-hand horizontal head has a single spindle for drilling the water drain cock hole.

An Archdale two-way drilling machine with a vertical head and a horizontal head at the left is used for the next operation. The vertical head carries twelve $\frac{7}{8}$ in diameter special end mills for milling the tappet drill clearance. There are two spindles in the horizontal head. One carries a combination reamer and chamfering tool for reaming and chamfering the front end clean out boss, while the other carries a penetrator twist drill for part drilling the oil gallery hole to a depth of $9\frac{3}{16}$ in from the front end. This head has reciprocating feed for deep hole drilling.

At the next operation three holes are drilled in the manifold side of the casting from the angular vertical head of a special Archdale two-way machine. The other head is horizontal and is tooled for part drilling the oil gallery hole to a depth of $9\frac{3}{16}$ in from the rear end, for counterboring the rear end cam bearing and for counterboring the rear end clean out boss. This machine is shown in Fig. 9. Once again attention may be drawn to the simple but effective work fixture.

The roller track now splits into two branches, one for six-cylinder and the other for four-cylinder blocks for the next three operations. There are differences in the number of heads employed in two of the machines in one row and the number for the corresponding machines in the other row. There are two reasons for this. The first is that while the oil gallery hole in the four-cylinder block is drilled through at the two preceding operations, the extra length of the six-cylinder block necessitates further drilling to break through from one hole to the other. The second reason is that the four-cylinder block has three camshaft bearings whereas the six-cylinder has four, so that in the

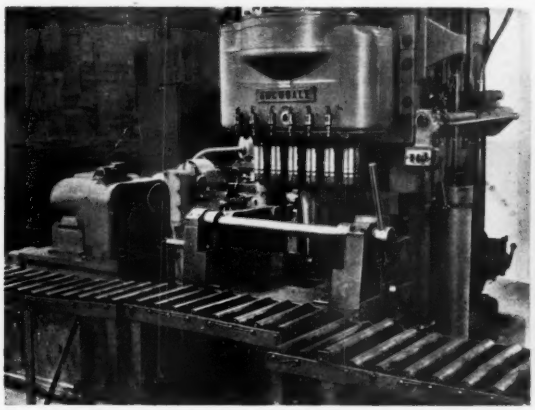


Fig. 11. The set-up for rough machining the bores of six-cylinder blocks. The horizontal head core drills the front intermediate cam bearing

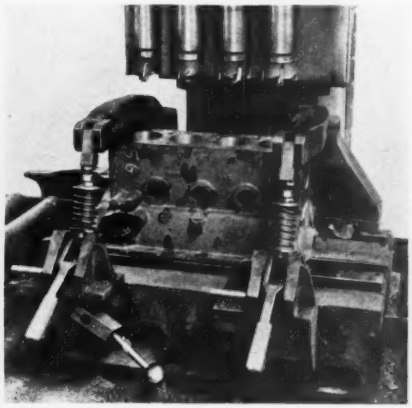


Fig. 12. The set-up for rough machining the bores of four-cylinder blocks. A simple, yet very effective method of clamping the work is employed

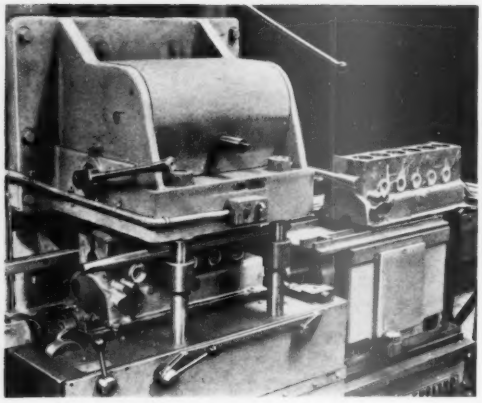


Fig. 13. Milling the main bearing faces on an Archdale plunge cut machine

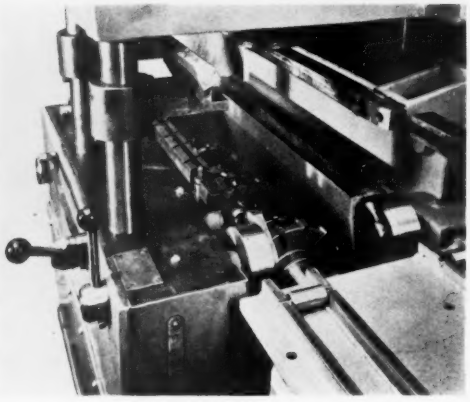


Fig. 14. The tooling on the machine illustrated in Fig. 13

one case only one intermediate camshaft bearing has to be core drilled while in the other there are two intermediate bearings to be core drilled.

For the first of these three operations an Archdale three-way drilling machine is used in each line. The machine on the six-cylinder line, see Fig. 10, has a vertical head tooled for drilling 12 tappet holes. At the left-hand end of the machine there is a two-spindle horizontal head tooled for drilling the oil gallery hole through and for core drilling the front camshaft bearing, while at the right-hand end there is a single spindle horizontal head tooled for core drilling the intermediate camshaft bearing.

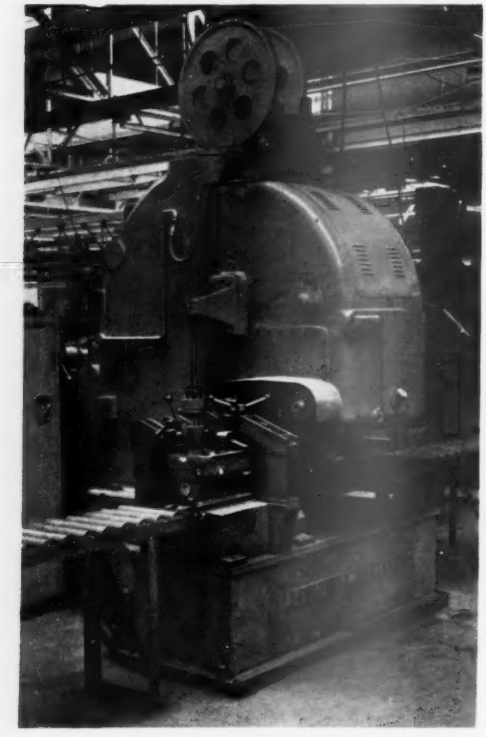


Fig. 15. Special Archdale three-spindle plunge cut miller

There is of necessity considerable overhang from the spindle nose to cutting faces of the tool for core drilling the rear intermediate camshaft bearing. To prevent deflection of the tool there is a retractable pilot bush plate which is actuated by the same mechanism as the locating plungers. When the plungers are retracted to allow the fixture to be loaded, the bush plate is below the base of the fixture; when the plungers are raised the bush plate is automatically brought into line with the core drill spindle. Fig. 10 shows the bush plate in the working position.

The machine for the four-cylinder block naturally differs in having only eight spindles in the vertical head for drilling the tappet holes. In addition, it also differs in that the horizontal head working on one end has only a single spindle and does not include a spindle for drilling through the oil gallery hole. The other horizontal head carries a core drill for the intermediate camshaft bearing. A pilot bush of the type described above is also used on this machine.

For the next operation a two-way Archdale machine is used. It is shown in Fig. 11 and comprises a six-spindle vertical boring head with snout type spindles and a single spindle horizontal drill head. The vertical head is tooled for rough machining the cylinder bores. Galtona cutters with five tungsten-carbide tipped blades are used. The front intermediate camshaft bearing is core drilled from the horizontal head. Once again a retractable pilot bush is used to prevent tool deflection. For the four-cylinder block, the corresponding machine has a four-spindle vertical boring head, but the horizontal head is not required. This machine with its very simple work fixture and clamping is shown in Fig. 12.

An Archdale two-way boring and drilling machine is used at the next operation. It has a six-spindle vertical boring head tooled for chamfering the top and bottom of the vertical bores. and a five-spindle horizontal head carrying combination tools for reaming and chamfering the welch plug holes. Out-feed tools are used for chamfering the bottom of the cylinder bores. At this stage the tracks converge to form a common track.

The bearing cap seats are finished for width and depth at the next operation, which is carried out by surface broaching on a special Cincinnati horizontal Hydro-broach. Between the broaching machine and the next machine in the sequence all the tapping holes in the head face and the front and rear ends are countersunk by means of an air drill suspended on a balancer above the roller track. The

casting is also blown out with compressed air.

At this stage the first machining on the crankshaft main bearing half-bores is carried out. The machine is an Archdale special two-way boring machine with a right-hand horizontal head for machining the half-bores and a rear horizontal head for reaming a 1·456 in diameter hole in one side of the block. This machine is arranged with the working position below the loading position. Side loading is employed and the component is pushed into the fixture and located at track height. Pneumatically - operated mechanism then lowers the fixture and the work to the machining position. This is by far the simplest method that can be devised for this operation since the work is lowered over the boring bar, the spindle traverse need only be that required for the longest bearing. Square shank tools are used. They are staggered to avoid having cutting forces all acting in the same direction. The six-cylinder block has four main bearings and the four-cylinder three. Four high-speed steel boring tools are used.

Once again the different size blocks follow separate tracks. The casting travels to the appropriate one of two Archdale special plunge cut milling machines. The machine on the six-cylinder line is tooled for milling both sides of the rear and intermediate rear main bearings and the inside of the front main bearing to final size. Both sides of the thrust bearing are milled to leave an allowance for finishing and four lock tags are milled. Figs. 13 and 14 show the work in position for milling and the cutters on their arbor.

The work fixture for this operation is built into the rise and fall head of the machine. Through loading is employed and is effected at track height. A fixed guide rail at the back and a pivoting guide rail at the front of the fixture help to facilitate loading. When the casting has been correctly located and clamped, the machine cycle is initiated and the head lowers rapidly towards the working position. It then feeds in slowly to the cutters. It is almost unnecessary to point out that the use of a rise-and-fall head for this operation gives a great saving in time as compared with any other method. On the six-cylinder machine, seven Galtona half-side milling cutters are used for the bearing faces and four staggered tooth slotting cutters for the lock tags. An interesting feature of this machine is that the rise-and-fall head incorporates a manually - operated winch for lifting the arbor and cutters to table height for tool changing.

After this operation and before the casting reaches the next machine it passes through a turn-over cradle in the roller track and is turned over to bring the sump side uppermost. The next operation is then carried out on a common machine, an Archdale special three-spindle plunge cut miller, see Fig. 15. Through loading is employed. The work fixture has fixed dowels in the top to register with the two location holes in the sump face and the work is raised manually by cam action to bring the sump face into contact with locating pads on the underside of the top of the fixture. This method is indeed employed at every operation where the sump face is uppermost. On this machine the three cutters mill the back of the dowel hole flanges at the rear end and the oil deflector groove.

Four oil holes from the crankshaft half-bearings to the camshaft bearings are then drilled on a special Archdale machine with a four-spindle angular head. Following this, the casting passes to an Archdale special three-way multi-drilling and tapping machine. On this machine, an angular head is used for drilling four oil holes from the crankshaft half-bores to the oil gallery. At

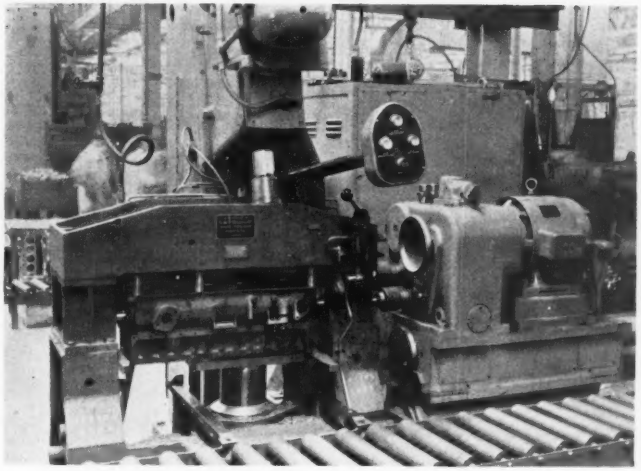


Fig. 16. Rough boring the cam and crank bearings on a six-cylinder block. At the same time the angular vertical head drills the bottom half of the distributor boss

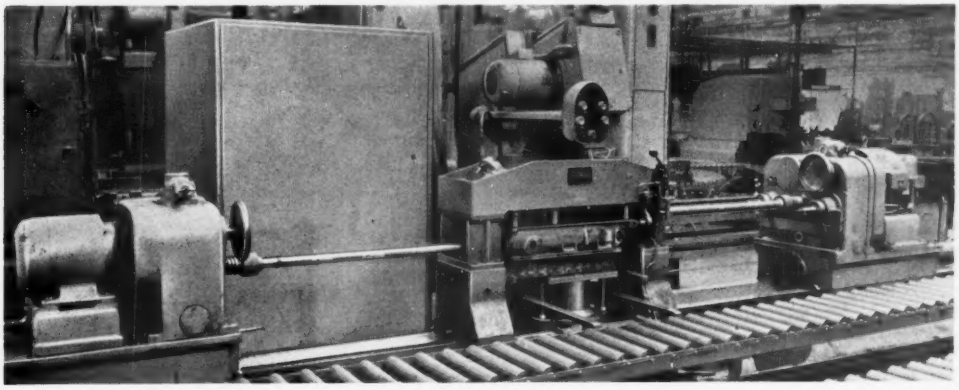


Fig. 17. An Archdale machine for finish boring the camshaft bushes and the main bearings. At the same time a hole in the distributor boss is tapped from an angular vertical head

the same time six holes are drilled from a right-hand horizontal head and eight holes are tapped in the front face from a rear horizontal head.

Another Archdale three-way drilling and tapping machine, which is common for both blocks, is used at the next operation. The machine has a vertical and two horizontal heads. The vertical head is used for drilling one oil hole from the sump to the oil gallery and another oil hole right through. Three holes are tapped from a horizontal head at the left and 18 from a horizontal head at the rear.

Once again the track diverges into two branches to serve two facing lines of machines. The first of this series of separate machines is an Archdale three-way tapping machine. It has a 31-spindle vertical head for tapping 22 oil sump holes, eight bearing cap holes and one oil hole. Through loading is employed with the front end leading. The front horizontal head is tooled to tap six holes in the manifold side of the block, and the rear horizontal head taps two holes in the fuel pump face and also mills a diameter on the wiper face. Mention may be made of the very simple type of work fixture used at this operation. Four steel pillars are mounted downwards from the machine head. Two of these carry location dowels in the lower face. The work is loaded on to a base plate and then lifted to bring the two reamed holes in the sump face into register with the dowels and to bring the sump face into contact with the faces of the four pillars to give the correct height location.

Before any further machining is carried out, swarf is blown out from the jacket and tapped holes in the sump and end faces, the welch plugs and the drain cock are fitted and the part-machined block is water tested. After the water test the tracks again converge to form a common line. On the common track the bearing seats are blown out and wiped clean ready for assembly of the bearing caps. The machining of the bearing caps is discussed later.

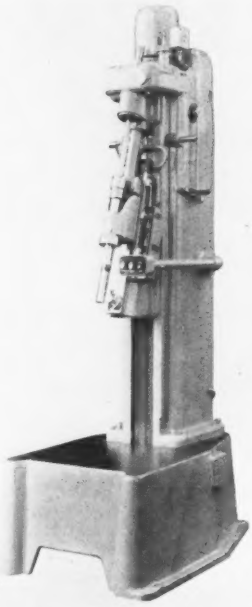


Fig. 18. Archdale hydraulic-feed production drill unit for fine boring the distributor bore, top and bottom

Extremely important operations which are fundamental to actual engine quality and performance now begin. At the first of these, four crankshaft main bearings are rough machined and the camshaft holes are semi-finish bored. An Archdale two-spindle horizontal boring head is used. At the same station there is also an angular vertical head at the rear for drilling the bottom half of the distributor bore. The combined machine is shown in Fig. 16.

A similar machine is used at the next operation at which the two-spindle horizontal boring head semi-finishes the crankshaft main bearings and finishes the camshaft holes ready for the insertion of the white metal bushes. A vertical angular head at the rear is used to drill a hole in the bottom of the distributor boss. On both machines the intermediate bearing steadies are slotted at the lowest point. The casting is loaded on to the base plate of the fixture at track height and is then raised pneumatically to $\frac{1}{8}$ in from the working position. By means of a handwheel calibrated in relation to both boring bars, the tools are brought to the lowest point so that they can pass freely through the bores and through the slotted bearing steadies. As soon as the bars are in position, the casting is lifted to the locating and clamping position. At the end of the machine cycle, the bars are stopped with the tools in the lowest position, the work is dropped $\frac{1}{8}$ in and the bars are with-

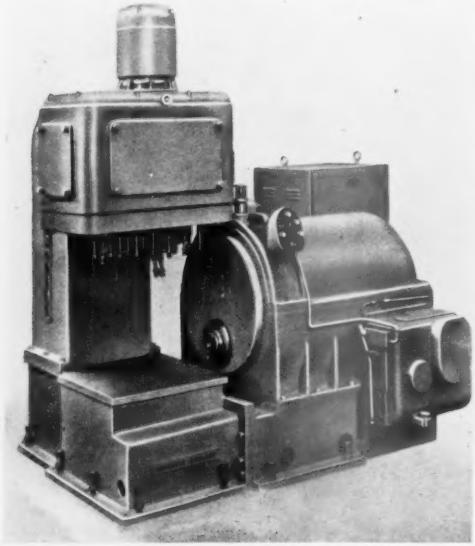


Fig. 19. An unusual combination of Archdale units, a multi-tapping head at the rear and a planetary milling head at the right

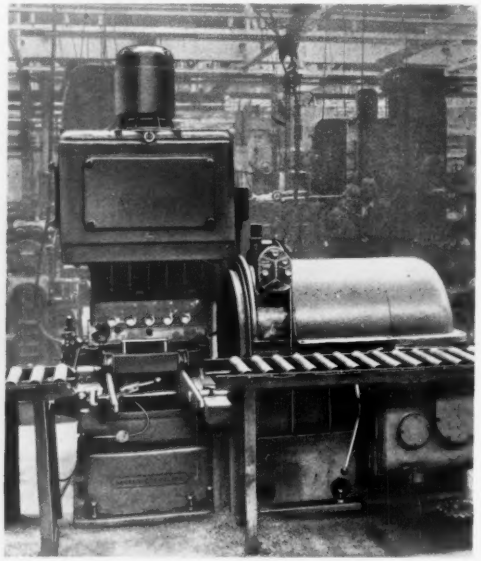


Fig. 20. A six-cylinder block in position on the machine illustrated in Fig. 19

drawn. The work is then brought down to track height and unloaded.

Before the white metal bushes are inserted in the camshaft holes their diameters are checked with Solex gauges. A Mills "Oilaulic" unit is used for pressing the bushings into the casting. The casting is then transferred to an Archdale special three-way boring and tapping machine. This has two horizontal boring heads, one at the left and one at the right, and an angular vertical head at the rear. It is illustrated in Fig. 17. The left-hand head is tooled for finishing the camshaft bush bores, while the right-hand head finishes the crankshaft bearing bores to size and also reams two dowel holes in the rear end face. This set-up is employed to ensure that the dowel holes are in the correct relation to the longitudinal axis of the crankshaft bearing bores to give correct assembly of the gearbox and clutch unit to the engine. Loading of this machine is effected in exactly the same way as on the machines for roughing and semi-finishing the crankshaft bearing bores and roughing and finishing the camshaft holes. The angular vertical head at this station is used for tapping a hole in the distributor boss.

Crankshaft bearing bores and camshaft bush bores are inspected for diameter and alignment before any further machining is carried out. All bearing caps, except that on the thrust bearing, are removed. It is almost unnecessary to say that the caps and the bearings have previously been stamped to ensure correct assembly later. In addition, the caps and the bearing seats are asymmetrical to ensure that they are assembled at final assembly in the same way as for machining.

The casting is then passed to an Archdale duplex horizontal boring machine tooled for facing, undercutting and counterboring both sides of the thrust bearing. Once again the work is loaded at track height and is then raised by pneumatic pressure to working height. At this stage the thrust bearing cap is removed and a slot is milled in it. It is then loaded in a tray with the other bearing caps for transfer to the engine assembly line on a separate roller conveyor.

An Archdale single-spindle hydraulic-feed production drill unit then rough and finish bores the top and bottom half of the distributor bore. This machine is illustrated in Fig. 18. To give adequate support to the tools, the boring bar has a long pilot at the leading end to register in a pilot bush in the fixture. For the remaining operations the block travels with the joint face uppermost. The turn-over is effected in a roller cradle in the roller track. All tapping holes not previously countersunk are countersunk by means of a compressed air drill suspended from a balancer above the track.

An unusual machine combination is employed for the next operation. It comprises an Archdale special planetary head milling machine and a vertical multi-tapping head. The

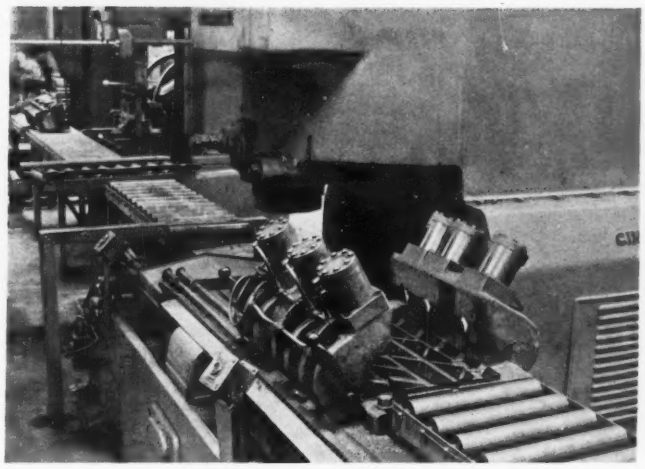


Fig. 21. The work fixture and hydraulic clamping arrangements on a Cincinnati machine for finish milling the cylinder block joint face

planetary head carries a Carbifine 8 in diameter milling cutter with 18 tungsten-carbide tipped blades for finish machining the rear end face, while the vertical head taps 16 holes, two of which are at an angle. The machine is shown in Figs. 19 and 20.

At this stage the head joint face is finish machined on a Cincinnati special vertical Hydromatic milling machine, see Fig. 21. Hydraulic clamping is employed and movement of a single lever applies three clamps on to the top face of the sump flange at each side. A face milling cutter, 7 in effective diameter and having 28 tungsten-carbide tipped blades, is used. The track now diverges to form two lines, one for six- and the other for four-cylinder blocks.

At the first operation on the separate track 12 tappet holes are finish reamed on an Archdale vertical multi-spindle drilling machine, following which the cylinder bores are semi-finished on an Archdale six-spindle vertical borer. This is a standard machine but attention may be drawn to the very simple work locating and holding fixture, similar to that shown in Fig. 12. Essentially, this comprises a base plate with location pads

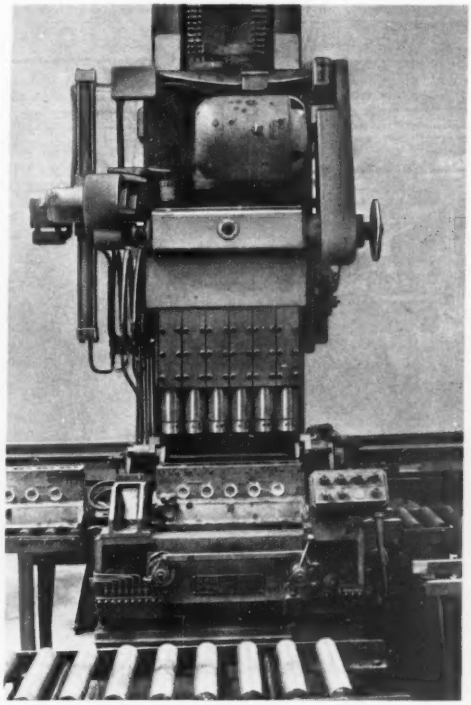


Fig. 22. Precision boring the cylinder bores on an Ex-Cell-O machine with an interesting automatic cycle

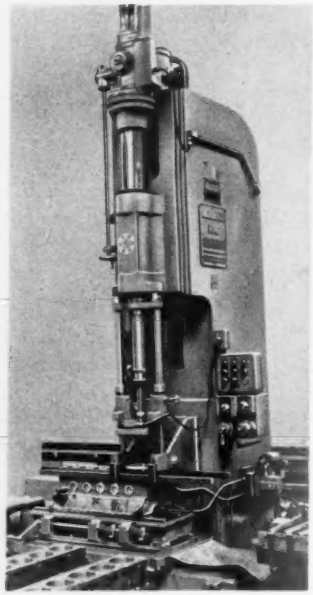


Fig. 23. Micromatic honing machine for finishing the cylinder bores

on which the sump face rests and two bridge-type spring-loaded, cam-action clamps, one at each end. Galtona five-blade, tungsten-carbide tipped cutters are used.

Precision boring on the cylinder bores is then carried out on a special Ex-Cell-O vertical six-spindle borer. This machine, which is illustrated in Fig. 22, has special mechanism for positioning the tools both at the top of the stroke and at the end of the down feed. At the top of the stroke, the boring bars are so positioned that the single-point tools in alternate bars are diametrically opposed. This means that during the actual machining the force exerted on the block by the tool in No. 1 bar is cancelled by an equal and opposite force exerted by the tool in No. 2 bar, and so on for all six tools. At the end of the cutting cycle, the spindles automatically come to rest individually with the tools all pointing the same way on the longitudinal axis of the block. When all the spindles are at rest, the work table is automatically indexed a short distance longitudinally, just sufficient for the tools to clear the machined walls on the return stroke. As soon as indexing is completed, the machine head automatically retracts and when the out position is reached the spindles automatically move round varying amounts to bring successive tools into diametrically-opposed positions. The clamps are automatically released and the table returns to the working position.

To complete the machining, the block is transferred to a single-spindle Micromatic vertical hydrohoner, Fig. 23. This is a gauge ring microsize machine on which the tool functions as an expanding plug gauge. A thermo-setting plastic shell is moulded about three sides of the abrasive stone and extends beyond the abrasive to form gauging tabs at each end of the stick. As the tool rotates and reciprocates through the bore, the cutting faces of the stick wear down. Since the abrasive and the plastic both contact the surface of the work, they wear at the same rate. Furthermore, the diameter of the stones and the plastic tabs, when in contact with the bore, is always equal to the bore diameter.

A gauge ring is mounted above the work in such a manner that the tool passes through it at every stroke. This ring has an inside diameter that is the same as the low limit for the specified cylinder bore diameter. It is free to float and align itself with the tool, but is prevented from rotating by a leaf spring. As the tool expands, and the bore increases in diameter, the tabs contact the ring. When the diameter of the tool equals that of the ring, the friction between the tabs and the ring is sufficient to flex the leaf spring and cause contact to be made with a stop pin. This contact grounds a low potential circuit that initiates the "to size" signal. The hone then collapses and the head retracts to bring the tool clear of the work.

At this machine the work is carried on a six-station indexing fixture so that as one cylinder is finished the work is automatically indexed along to bring the next cylinder into position. It is perhaps worth pointing out that Vauxhall Motors Ltd. do not attempt to produce a complete mirror finish in the cylinder bores. On the contrary, the machining has been definitely planned to avoid this. The amount of metal removed at the honing operation is not sufficient to remove all evidence of tool marks caused at the preceding precision boring operation. In effect, what is produced is a cylinder wall comprised of a multiplicity of very highly finished surfaces divided by narrow and shallow depressions which, in service, act as oil reservoirs.

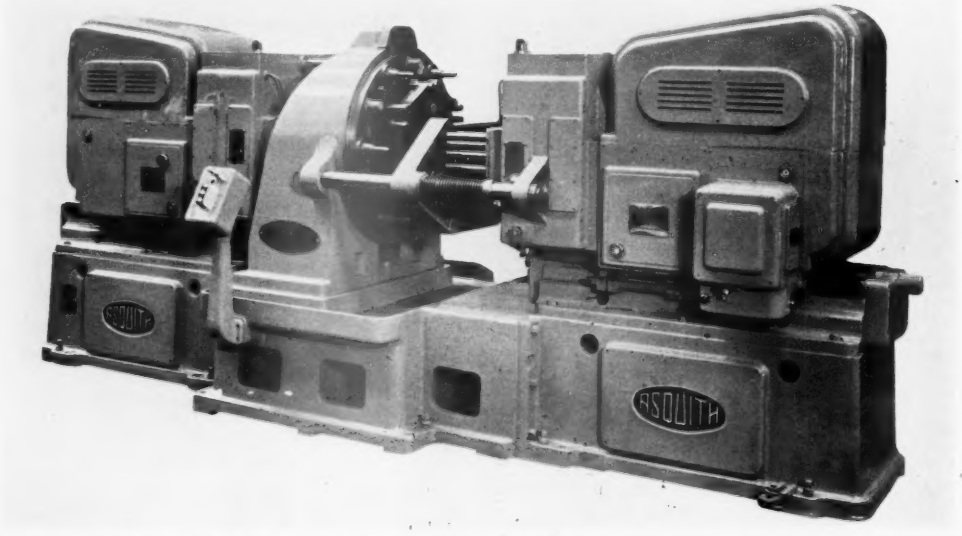


Fig. 24. A special Asquith multi-drilling machine with a six-station trunnion fixture for drilling, reaming, recessing, chamfering and spotfacing composite bearing cap castings

As soon as the honing is completed the block is inspected for bore size. Solex gauging equipment is used, and every bore is graded. The roller tracks then converge to form a common line on which the machined casting is washed in a Dawson machine with directed jets, and then blown-out with compressed air. A complete inspection in a turn-over fixture with special lighting to allow all bores and through-holes to be inspected easily, is then carried out. The rear gap and plate are then assembled and the bearings caps are loosely assembled in the correct positions and the cylinder block is ready for transfer to the engine assembly conveyor.

Crankshaft bearing caps

The bearing caps for both four- and six-cylinder engines are machined from cluster castings. A cluster casting for a six-cylinder engine comprises a rear and a front cap and two intermediate caps, while the four-cylinder cluster comprises one rear, one front, and one intermediate cap. The same machine line is used for both four- and six-cylinder engine bearing caps. In general the machining methods are the same for both. These notes deal only with the six-cylinder engine bearing caps.

A Weatherley Oilgear single-slide vertical broaching machine is used at the first operation. A three-station fixture is mounted on the shuttle table of the machine with each station tooled for broaching different elements. Three passes through the machine are necessary to complete the broaching on one cluster casting. At the first station all the joint faces and tenon widths and a 45 deg chamfer are machined; at the second the front bearing face is broached; and at the third all four half-bores are broached to leave an allowance for rough and finish boring when the caps are assembled to the cylinder block.

The composite casting is then transferred on a wire mesh conveyor to a special Asquith horizontal multi-drilling machine with a six-station trunnion fixture, see Fig. 24. The right-hand head of this machine has 28 spindles and the left-hand head 24 spindles. In the six-cylinder cluster casting, eight holes are drilled, reamed, recessed and chamfered, and four of them are also faced on this machine. Loading and unloading are carried out at an idle station, while the machine is working at the other stations. Guards are fitted to protect the operator from risk of injury from the spindles.

At the second station, two bolt holes are drilled halfway through from the right-hand head to leave an allowance for reaming, while from the left-hand head two bolt holes are centred with a spot drill. The right-hand head at the third station is tooled to spotface and countersink four bolt holes and the left-hand head for drilling four bolt holes through. At the fourth station, six bolt holes are counterbored from the right-hand head, and four bolt holes are drilled through from the left-hand head. The left-hand head at the fifth station is idle while the right-hand head is used for countersinking four and counterboring two bolt holes. At the sixth and final station, the right-hand head is idle while the left-hand head reams two bolt holes.

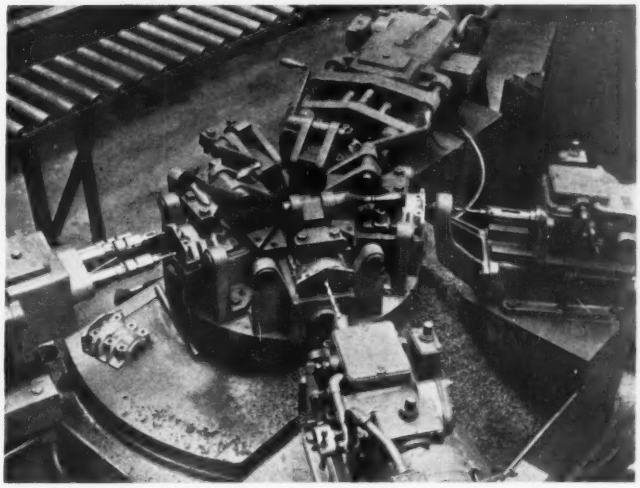


Fig. 25. The tooling on a special Pollard machine for drilling and tapping bearing caps for the new Vauxhall engine

The six-station fixture rotates about the horizontal axis. It has a sliding bush plate supported on guide bars. Each station is arranged to accommodate a composite casting. Location is taken by hardened strips from the joint face and tenon width and endwise by a stop that engages the front bearing face. A beam type clamp and compensating piece secures the work in position. The indexing plate is mounted on two large angular contact anti-friction bearings. It has a ratchet motion which prevents indexing in the wrong direction, and also makes it impossible to over-index in the correct direction. The ratchet mechanism is interlocked with the machine motions by a locating plunger shaft attached to the left-hand multi-head.

Two substantial shafts support the moving bush plate. Each has one end secured in the multi-head and the other is supported in the fixture. The bush plate moves forward under spring pressure and locates on two dowels on the rotating fixture. Two studs are arranged to withdraw the bush plate when the heads recede. To facilitate maintenance, all the tool guide bushes are fitted with liners. The angle bracket which carries the rotating plate is arranged with a swarf chute to deliver swarf to the front of the fixture for convenient removal.

One push button controls the machine cycle. On the right-hand head, it initiates quick traverse to start feed position, feed at fast rate for drilling, auto-change to slow rate for facing, slow feed to dead stop, dwell with the spindles running, quick traverse to rear position. At the same time, the cycle for the left-hand head is: quick traverse to feed position, feed to electrical limit, quick traverse to rear position. Electrical interlocks are arranged on the locating bar attached to the left-hand head in such a manner that in the event of incorrect indexing both units return to the start position before the tools are exposed to the possibility of damage.

On the left-hand head the drill penetration is 2·3 in per minute. On the right-hand head it is 2·2 in per minute but before the end of the drilling feed it is automatically reduced to 0·75 in per minute for the recessing and facing operations. The actual machining conditions are:—

Drilling: $\frac{7}{16}$ in diameter, 440 r.p.m., 0·005 in feed per revolution, approximate cutting speed 50 ft per minute.

Reaming: $\frac{29}{64}$ in diameter, 280 r.p.m., 0·008 in feed per revolution, approximate cutting speed 30 ft per minute.

Recessing: $\frac{13}{16}$ in diameter, 239 r.p.m., 0·003 in feed per revolution, approximate cutting speed 50 ft per minute.

Chamfering: $\frac{9}{16}$ in diameter, 340 r.p.m., 0·002 in feed per revolution, approximate cutting speed 50 ft per minute.

Spotfacing: $1\frac{1}{16}$ in diameter, 180 r.p.m., 0·004 in feed per revolution, approximate cutting speed 50 ft per minute.

Although the casting is still composite, the next operation really concerns only the front bearing cap. It is performed on a machine that has been built specially for the purpose by Frederick Pollard and Co. Ltd., Leicester. The machine is shown in Fig. 25. There is a five-station fixture in which four holes are drilled, one of them being angular, and three holes are tapped. The station sequence is:—

First: Load.
Second: Drill three tapping holes.
Third: Drill angular hole half way.
Fourth: Finish drilling angular hole.
Fifth: Tap three holes.

The drilling stations are operated by auto cam units and the second station carries a three-spindle multi-head. At the fifth station the three-spindle tapping head is operated by an auto screw-feed unit. The indexing table is power operated and is controlled by a single lever. Loading is carried out while the machine is in operation. A completely automatic cycle is initiated by push button. It causes all the units to approach the components, drill or tap, return to starting position and then stop. The table is then indexed and another cycle is initiated. Electrical interlocking prevents indexing of the table while the units are in operation. There is a time cycle of 45 seconds, including table indexing.

For the next operation the cluster casting is mounted in a Maximinor multi-tool lathe on which an outside radius is turned on the front and rear caps, and oil seal grooves are machined in the front and rear half-bores. At the next operation also only the front and rear caps of the cluster are machined. In each of the half-bores of these caps, a recess and an oil deflector groove are machined on a Cincinnati plain Hydromill. This machine has two fixtures, one on either side of the milling cutters, so that castings are machined on both table strokes. At the final operation on the composite casting the lock tag slots are milled on an Archdale horizontal milling machine.

The castings are then split into individual caps on a Cincinnati plain Hydromatic milling machine with a two-way feed cycle. There are two fixtures on the machine so that one cluster is split into individual caps for every table stroke. This completes the operations on the front and intermediate bearing caps, but further operations are carried out on the individual rear bearing cap.

At the first of these individual operations two slots are milled on an Archdale horizontal milling machine; at the second two angular holes are drilled on an Archdale sensitive two-spindle drilling machine; and to complete the operations, four holes are drilled, two at a time, on a Herbert two-spindle V type machine. The machine line for crankshaft bearing caps is installed between two loops of the cylinder block line in such a position that machining of the caps is completed at a point adjacent to the station at which they are required on the cylinder block roller track. They are transferred to this track in sets in tote pans.

(*To be continued*)

MACHINING OF METALS

A FILM entitled "Machining of Metals" has been made by the Shell Film Unit in collaboration with the Production Engineering Research Association of Great Britain. It shows the principles on which all machining operations are based and tells the story of the advance of cutting techniques and the research on which this progress is based. The early part of the film shows how metal is removed from the workpiece by the wedging action of cutting tools. Later the manner in which the nature of the workpiece, the tool and other factors affect machining operations is explained.

Much of the material for the film was shot in the laboratories of the Production Engineering Research Association and facilities for filming were also provided by B.S.A. Tools Ltd., Edgar Allen & Co., Ltd., Benjamin Huntsman Ltd., William Jessop & Sons Ltd., Vauxhall Motors Ltd. and George Wailes & Co., Ltd. The sequences filmed at high speed showing chip formation and the application of cutting fluid were shot at up to 3,000 frames per second or 125 times normal speed by S.I.M.P.L. Ltd. with a specially designed Eastman Kodak 16 mm. camera.

The wedging action in machining—a still from the film

The film runs for 27 minutes and may be borrowed free of charge from Shell Mex & B.P. Ltd. and from the Petroleum Films Bureau, 29, New Bond Street, London, W.1. It does not set out to teach the technique of machining but is rather a survey of principles and of the methods by which machining efficiency may be increased. The instructional value of this film is undoubtedly high. (2012)

ELEKTRON DOUBLE-DECK BUS BODY

EXPERIENCE gained in Germany on the construction of light-metal vehicles, it is reported in *Motor Body*, February, 1952, has been utilized to explore the possibility of building a double-deck bus of Elektron, a magnesium alloy. The entire body is designed and calculated as a single box-like element, representing in effect a statically indeterminate structure. Hence, all the main members can be used for load carrying, and the material requirements are thereby minimized. Side walls, floors and roof can be fabricated separately and easily assembled. Figures show (1) the static stress diagram of the side wall, (2), the two extruded sections forming a vertical column, (3) the method of fixing the corrugated sheet floor to the internal horizontal beam, (4) a section through the roof attachment, (5) the ease of assembly of the structure.

A table gives estimated weights of the various structural parts. The weight of an all-Elektron body with detachable panels would be 4,992 lb against 6,880 lb for a standard composite double-deck body with aluminium panels. Instead of the external panels being riveted, and employed to support the load, which would permit further weight saving, they are screwed to wooden battens to facilitate maintenance and repair work.

The superstructure is composed of six simple extrusions which eliminate costly fabricating work in the shop. Castings dispense with complicated deformations on the roof and the body corners. The constructional work consists mainly of cutting and trimming sheets and extrusions, drilling and riveting, labour costs being thereby minimized. Whenever possible, the use of timber has been avoided to effect, in comparison with existing designs, a weight-saving of 66 per cent on the floors and 76 per cent in the frame work. The simplicity of design should largely offset the comparatively higher cost of using wrought Elektron alloys.

With a new design and a new material, the question of strength is vital. Detailed calculations of stresses, especially of the largest bending moments which occur in the side wall, are essential. A method of calculation, based on that applied to the structure of a steel-framed building, is described with the help of diagrams of the bending moments and shear forces present in the framework as a result of the external loads.

Particular questions in relation to such stress calculations are discussed in four subsequent articles in the Journal. (*M.I.R.A. Abstract No.* 5808).

PLASTICS BODY CONSTRUCTION

A Survey of Recent Developments and Methods

THE use of plastics as a constructional material for motor bodies is far from being a new development. Articles on the subject appeared in the *Automobile Engineer* in August, 1940, May and October, 1941, and September, 1943. The first is a survey of some German patents on the subject; the Auto Union group built a number of plastics-bodied vehicles before the war. The second two articles give details of a plastics body made by the Ford Motor Co., of America, and the last describes a number of plastics materials and production methods. A photograph of a British-built, plastics-bodied car appeared in the Press in March of this year. Very few details were given, but it was stated that experimental work began as early as 1937, and that one body, built nine years ago, has been run satisfactorily for 85,000 miles.

It was also reported in the Press that the manufacture of some 2,000 plastics-bodied cars is planned in Eastern Germany for this year. Although this announcement was made several months ago, so far as is known, none of these vehicles has been seen in the West, and no further details are available at present.

During the war as a result of shortages of more conventional materials of construction and the uncertainties of the supply position, considerable advances in plastics technology were made. Post-war developments are most interesting. This is because more is now known about production and design techniques. Moreover, it is only recently that engineers generally, and automobile engineers in particular, have come to realize fully the potentialities of this class of material, and have turned seriously to its application.

More than four years ago, Mulliners Ltd., of Birmingham, built several prototype bodies. At least one of these, made of paper-reinforced resin plastic, was mounted on a Lanchester chassis, and proved very satisfactory in service. A similar body made by this manufacturer is illustrated in Fig. 1. It was cured with heat in an autoclave, a rubber bag being used to press it into the mould and to apply pressure during the curing process. Although it was built with a timber framework and a screwed-on sheet metal dash structure, it does not necessarily follow that this line of approach to the design will be adopted in future.

A few years ago, Mr. George May, of Wembley, made some plastics outer panels for a Ford Prefect door, Fig. 2. The plastics used was Durestos, made by Turner Brothers Asbestos Co. Ltd., of Rochdale. This material is available in the form of a pliable, resin-impregnated, asbestos felt, in three grades and various thicknesses. It can be successfully laminated by low-pressure moulding, using a rubber bag to apply the pressure. Alternatively, rollers, squeegees, and other tools may be used to form it to the shape of the mould. The door panels were made by hand, the material being cured in an electrically heated oven, without using pressure. As the curing proceeded the temperature was gradually increased from cold to 110 deg C. to complete the cycle. The resulting panel weighed 4 lb 15 oz as compared with the 19 lb 14 oz of a metal panel.

The mould was formed by pressing several layers of Durestos felt on the waxed outer surface of a door, the wax being used as a parting agent. Durestos sheets are tacky in the uncured state, so adhesion between layers was easily effected. After curing, the mould separated readily from the door. It was then waxed inside, and the three-ply laminate of Durestos felts, forming the door panel, was pressed into it by hand. The door inner panels were placed in position, and the Durestos turned around the flanges, in the same way as a metal panel, to form a Dutch bend. The assembly was then ready for curing.

Another motor body made of plastics materials is now in production on a small scale in America, by the Glasspar Co. of Costa Mesa. It is made of Vibrin, a polyester resin, reinforced with glass mat and glass cloth, manufactured by the Owens-Corning Fibreglas Corp. Vibrin is produced by the Naugatuck Chemical Division of the United States Rubber Co. The proportions of the constituents are approximately 65 per cent plastics and 35 per cent glass. Although at present only one model, a sports body for a modified Willys chassis of 8 ft 4 in wheelbase, is in production, the manufacturers hope that several types will be available, perhaps later this year, for mounting on different standard chassis.

In general, the thickness of the shell is 0·2 in. The body now being produced weighs approximately 185 lb in the condition shown in Fig. 3, and it is sold at a price of 650 dollars which is stated to be less than one-fifth of the price of most similar custom-built, metal bodies. These figures show that, by virtue of the fact that there is a considerable saving in weight, the material cost is not so excessive as it would appear to be at first sight.

Production is a relatively simple process well suited to the small-scale manufacture of specialist coachwork. As with steel bodies, the first stage is to build a mock-up. That made by the Glasspar Co. was of timber and plaster. An extremely smooth finish is then given by sealing and sanding it, Fig. 4.

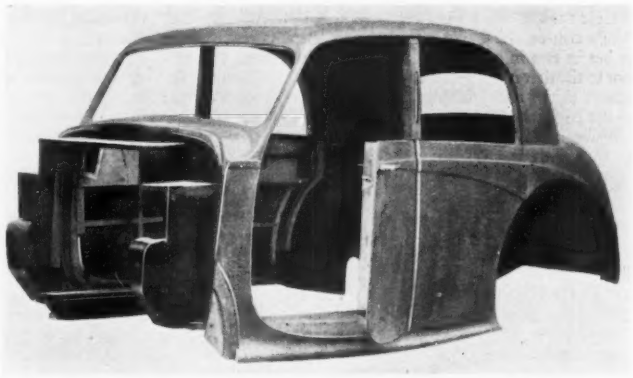


Fig. 1. A plastics body, for a Lanchester chassis, made by Mulliners Ltd., Birmingham

This is important as the finish of the mock-up is imparted to the female mould, and hence to the bodies produced from the mould.

After waxing the mock-up a coat of polyvinyl acetate is applied. This treatment ensures that the production mould will break away cleanly and easily. Next, a fast curing coat of the polyester resin is brushed on the plaster mock-up as an overlay. It ensures the production of a smooth finished surface, free from pinholes and rough spots, in the mould.

A layer of glass mat, and then another of glass cloth is laid on. After this, the resin is applied over the cloth and squeegeed to remove air bubbles and to ensure even distribution Fig. 5. Altogether five layers of glass and resin are employed. Following the curing process, which may be speeded up by using infra-red lamps, steel brackets are attached to give it rigidity, and to facilitate handling. While still on the mock-up, the mould is cut in two in a transverse plane adjacent to the driver's seat. Flanges of glass cloth and plastics, are attached to the edge where the mould was cut, and they are then drilled for bolts, Fig. 6. With this arrangement the two parts can be joined together again, and smoothly aligned after the next process which is the breaking away of the two pieces from the mock-up. The inside of the mould is carefully polished to ensure a smooth surface on the bodies that are to be produced from it. Finally, the two mould parts are joined together by bolts through the flanges, and all is ready for production.

First, the inner face of the mould is given a coating of wax, followed by another of polyvinyl acetate parting agent to ensure easy release of the body. Then a fast curing coat of resin is applied. This coat is an essential, once again, so that the surface of the finished body will be smooth and free from pinholes. A layer of glass mat and glass cloth is laid on, and plastics is applied over the cloth, and squeegeed to distribute it uniformly and to eliminate air bubbles, Figs. 7 and 8. When this has hardened, the process is repeated until the desired thickness is obtained.

The body is allowed to cure in the mould, infra-red lamps being used to hasten the process. It is then removed, buffed, and the corners smoothed, Fig. 9. Finally the paint is applied. This last part of the process might be eliminated if pigment could satisfactorily be incorporated with the plastics.

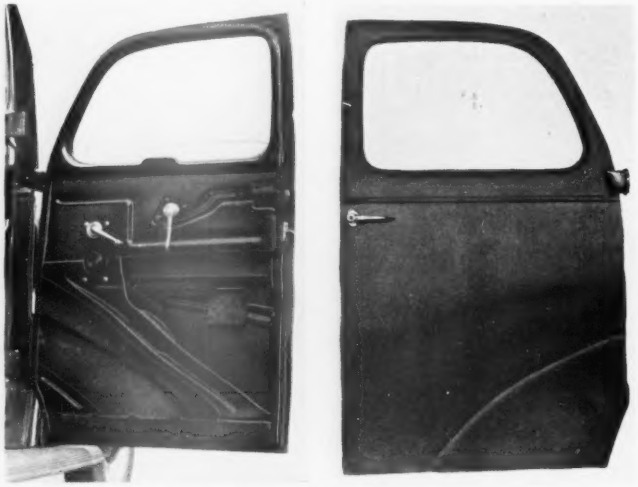


Fig. 2. Ford Prefect door with a Durestos outer panel

Impregnated glass fibre material, like many other plastics, is remarkable for its resilience. In a test, the car was run against a tree. Although the impact knocked off the bark, very little damage resulted to the body. There was no dent, the material having sprung back to its original shape after the blow. Some of the bark was embedded into the plastics, and there was a crack some 14 in long. The repair was finished, except for painting, in one hour. First the surface of the crack was buffed, Fig. 10. The glass fibre was then laid on the crack and coated with plastics, Fig. 11. Finally the repair was painted.

General properties of plastics

To describe anything as being made of plastics is as indeterminate as to say that it is made of metal, for there are probably as many different types of plastics as there are of metals. Plastics in the form commonly employed in electrical components are completely unsuited for the manufacture of motor bodies. The materials that have so far been used for this purpose are of synthetic resin, reinforced with one of several varieties of strong fibre. Many of these fibres have a tensile strength considerably in excess of that of steel. For instance, the tensile strength of glass fibre is 250 ton in^{-2}, and of chrysotile asbestos 95 ton in^{-2}. It is in order to make use of this very great strength that the fibres are bonded with resin. This impregnating material is comparatively weak and, as a result, the tensile strength of the finished sheet is much lower than that of the fibres, although it is still comparable with that of mild steel, and in some cases it is better. From Figs. 12 and 13, it can be seen that as far as strength is concerned, the relative proportions of resin and reinforcement are critical.

One of the principal disadvantages of many plastics materials is that their tensile strength is directional, being greatest parallel to the fibres. This does not apply if the fibres are orientated indiscriminately, but under these conditions the greatest possible strength is not obtained. Another serious disadvantage is that the shear strength of plastics is small compared with that of metals. Furthermore, it is expensive when expressed in terms of cost per lb of material. However, this is, to some extent, offset by the fact that the weight of plastics needed is something like one half that of the steel required for the same components. The time necessary for its fabrication into panels for a motor body is very much greater than that required to manufacture pressed steel panels. Again, this disadvantage can be offset to some extent by integrating the structure, so that one component is used where previously several were fabricated together. There is little doubt that as far as the time required for manufacture is concerned, the processing of plastics panels compares favourably with panel beating.

In view of the light weight and low shear strength of plastics, thicker panels than those used for metal bodies are required. Because of the resilience of the material and the thickness of the panels employed, dents are not formed as a result of a blow. Water absorption properties

are important. Some plastics, paper-based phenol formaldehyde laminates for example, lose as much as 18 per cent of their strength after twenty days in an atmosphere whose humidity is 75 per cent. However, there are many others that do not suffer any ill effects from moisture, among these are asbestos, and glass fibre-based materials.

Boats and Engines, Ltd., of Weybridge, who make dinghies of Fibreglass and Nuron resin, claim that dinghies of their manufacture, after having been laid up in the sun on tropical shores for as long as two years, can be used in the water directly, without any painting or renovation. They also state that no trouble has been experienced from distortion. In a recent television demonstration of these products, the following test was shown. A 6½ lb weight was dropped from a height of 3 ft onto a small rectangular panel, 8 in by 5 in, of $\frac{5}{16}$ in African mahogany, supported on a frame. It split along the grain and the weight fell straight through. The procedure was repeated with a 16 S.W.G. sheet of aluminium alloy in which a $\frac{1}{2}$ in dent was made on the first drop. However, when a $\frac{1}{16}$ in thick sheet of Fibreglass plastics was tried, the weight had made no impression on it after 24 drops. During early experimental work in connection with repairing damage, an operator was told to knock a hole in the side of the boat with a hammer. This he was unable to do, and a chisel had to be used for this purpose.

It is the resins that are effected principally by temperature although, where reinforcement materials unaffected by heat are used, the plastics sheet retains its properties at higher temperatures than where the reinforcing material is for instance, paper. In general, plastics are available that may be used in the temperature range from —60 deg C. to +130 deg C., without serious loss of strength. Many plastics have a high co-efficient of expansion. This is a disadvantage where they have to be attached to a metal or timber framework. The asbestos phenolic class of material is one of the best from the point of view of thermal expansion. Most plastics are resistant to corrosion. Experimental work with aircraft has shown that surfaces whose inclination from the horizontal are less than 15 deg show little or no sign of erosion, but where the angle is more than 60 deg, erosion is proportional to the sixth power of speed. At the relatively low speeds of motorcars, little trouble is likely to be encountered.

Resistance to fatigue is often as much as 50 per cent higher than that of a heat-treated aluminium alloy. The rate of loading with respect to time has a marked effect, and the limiting creep stress at normal atmospheric temperatures is much lower than the nominal ultimate tensile strength of the material. For this reason the conditions under which mechanical tests are carried out are important and should be specified, particularly with regard to both temperature, and rate of loading. The hystersis of reinforced plastics is 20 or 30 times that of metals. This, by increasing the structural damping, has a marked effect in reducing noise in a vehicle. Another advantage from this point of view is that, by virtue of the greater thickness of plastics panels compared with steel ones, they are more stable.

Resins

Phenolic resins set by condensation reaction, that is to say, water is evolved chemically during the setting process. Moreover, setting is inhibited by the presence of water, and this helps the resin to flow under curing conditions. A great deal of experimental work has been done on phenolic resins at the Royal Aircraft Establishment, Farnborough. It has been found that if the water can be removed continually while curing, after inserting them in the mould in a damp, lightly condensed state, they may be set satisfactorily at low pressures. The removal of water is effected by thoroughly ventilating the mould, and subjecting the resin to a partial vacuum during cure. Non-absorbent reinforcing materials, such as asbestos or glass fibre are, of course, most suitable for use with this resin.

Nuron 100 is a methacrylated alkyd, contact pressure, laminating resin which has been developed by I.C.I. Plastics Division, Welwyn Garden City. It differs from the usual thermo-setting resins of the phenolic or the urea formaldehyde types in that it cures by double bond polymerization, rather than by condensation reaction with the elimination of water. It contains no solvent, and the whole of the original material reacts to form a cross-linked, thermo-setting product that is insoluble and infusible.

This material is supplied in two parts; Nuron 100-A, a viscous, non-volatile brown liquid, and Nuron 100-B, a clear to pale yellow free-flowing liquid. In addition, a catalyst is employed. All the constituents should be stored in a cool place, out of direct sunlight. Under these conditions, they should remain usable

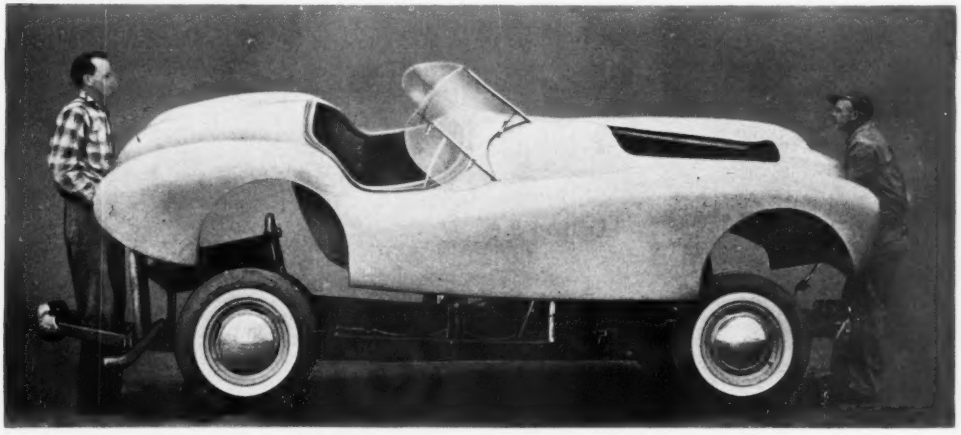


Fig. 3. This glass fibre-polyester body, made by the Glasspar Co. of Costa Mesa, weighs only 185 lb

Fig. 4. The plaster mock-up is sanded so that it will impart a smooth finish to the mould

Fig. 5. A concave mould is made with polyester resin, straight-fibre glass mat, and woven glass cloth

Fig. 6. Flanges of glass cloth and plastic are attached at the junction, and drilled for bolts

Fig. 7. A squeegee is used to ensure uniform penetration, and to eliminate air bubbles

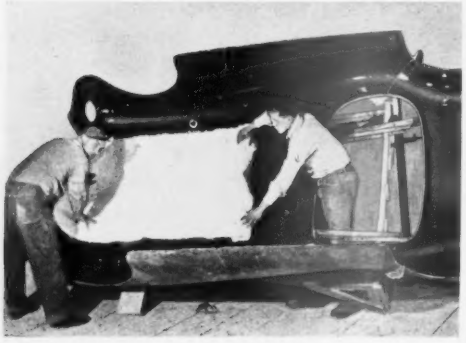


Fig. 8. The mould is positioned conveniently for laying on the cloth and resin

Fig. 9. The final operation before painting is cleaning up the edges with a disc sander, and smoothing the surface

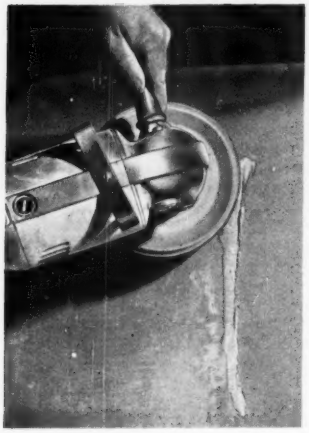


Fig. 10. Preparing a crack for repair

for at least three months. The catalyst, benzoyl peroxide, must be treated with some caution. In the damp condition, it is harmless but, when dry, it is liable to explode on being struck or heated, so the water content must be maintained above 30 per cent. The damp lumps are best broken by crushing between the fingers.

Mixing takes about 20 minutes. One part by weight of benzoyl peroxide is added to 10 parts Nuron 100-B, and dissolved. This process may be hastened by immersing the container in a bath of hot water. The solution is then slowly poured into 90 parts by weight of Nuron 100-A, and the stirring continued until the mixture is homogeneous. On standing, the resulting mixture will tend to gel. A mixer of the Hobart type may be used, but hand stirring is quite effective. Under normal conditions, the time during which it remains usable is about four hours, but it may be prolonged to 24 hours or more by gentle mechanical stirring. A word of caution is necessary; no naked flame should be allowed near the catalyst during the mixing process.

This resin can be used to impregnate a variety of reinforcing materials. It is particularly suited for use with glass fibre cloth, with which the best results are obtained if the cloth is previously heated at between 300 and 350 deg C. to drive off moisture, and to de-lubricate it. Impregnation can be effected by brush application, or by dipping and removing the excess liquid by rolling. If sheets of impregnated cloth are laid on the mould, it will be found that they are tacky enough to laminate satisfactorily under hand pressure. A resin content of about 40 per cent for glass fibre cloth, and 50 per cent for other reinforcing materials should be the aim. The curing process must be commenced within about eight hours of impregnation.

The heat needed to cure the resin may be applied either by putting the whole component into an oven, or by using hollow metal moulds, or pipes through which steam may be passed. The curing temperature is from 100 to 120 deg C. At 100 deg C, using 1 per cent benzoyl peroxide, a $\frac{1}{16}$ in thick board of impregnated glass fibre will cure in 20 minutes. At 110 deg C, the time may be cut down by half.

Vibrin is a trade name, given by the Naugatuck Chemical Division of the United States Rubber Co., to a whole family of plastics raw materials known as polyesters. Many advantages are claimed for this material. It is fast curing and thermo-setting. Like Nuron, there are no volatile by-products, and this simplifies the curing process. Moreover, it can be fabricated without high pressures or temperatures. Its dimensional and chemical stability is good and, over a wide range of temperatures, the material does not change its properties with age. The method of application has already been elabroated upon in the description of the American plastics body.

Another resin of the polyester type is made in this country. It is Marco Resin, manufactured by Scott Bader and Co. Ltd., of Wollaston, Wellingborough. It is stated that panels of this material reinforced with glass fibre, and only $\frac{1}{16}$ in thick, have adequate strength for motor bodies. The total weight of a body for a car, the overall length of which is 15 ft, is less than 100 lb. The resin is cold setting, its curing time being approximately four hours. However, the time may be reduced by heating, or it can be varied by using different proportions of the constituents. It is applied in three parts, the resin, a catalyst, and an accelerator.

Reinforcing materials

So far, the two reinforcing materials used most successfully for motor body construction have been glass fibre and asbestos fibre. Of these, the glass polyester materials are the stronger and tougher but, although the asbestos phenolic materials are weaker and more brittle, they are stiffer, cheaper and more suitable for elaborate mouldings.

Durestos, used by Mr. George May for making a Ford Prefect door, is typical of the asbestos phenolic plastics. It consists of a thin felt of chrysotile asbestos fibres impregnated with the phenolic resin, and it is normally supplied in large sheets in the soft state. The uncured sheets have a working

Fig. 11. Laying on the glass mat and resin

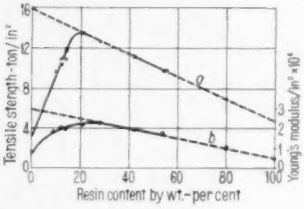
life of several months, and they are dry, clean, and easy to handle before curing. When cured under high pressure the specific gravity is in the region of 1·8. After vacuum moulding it is about 1·2, and pressureless mouldings may have a specific gravity as low as 1·0. The specific mechanical properties of pressureless moulded panels are about 15 per cent lower than those obtained at high pressure. Conversely, the properties obtained by vacuum moulding are slightly better than those given by the high pressure method. Specific mechanical properties are those such as ultimate tensile strength, and Young's modulus, divided by the specific gravity. They give an indication of the strength weight ratio. Plastics generally, because of their very light weight have particularly good specific mechanical properties. Durestos has good weathering properties. It burns very slowly and tends to be self-extinguishing, and the co-efficient of thermal expansion of this material is of the same order as that of carbon steels.

Long fibres give better strength properties to the material than short ones. When laid parallel, a process which has not yet been perfected with asbestos fibre, the strength is greatest, but it is uni-directional. However, by crossing the laminations at calculated angles, material of the desired all-round strength could be produced.

Gordon Aerolite, developed by Dr. N. A. de Bruyne, of Aero Research Ltd., is at present the only uni-directional material available. Its shear strength is very small, but its specific longitudinal tensile and compressive strength and stiffness are about 50 per cent better than those of Duralumin. It is a cellulose-reinforced

material, of flax fibres and phenol formaldehyde resin, moulded at high pressure. Owing to its relatively high cost, it is only suitable for use in the form of inserted strips to provide local reinforcement at points of high stress.

Glass fibre seems to be the most practicable material for the manufacture of motor bodies. It is best used for low pressure mouldings because,



a Tensile Strength
b Young's modulus

Fig. 12. The proportion of resin to reinforcing material is important

under high pressure, the glass fibres can be damaged. Brush application of the resin is perhaps easiest when the material is woven into the form of a cloth. Moreover, the surface finish, which is dependent to some extent on fineness of the weave, is better. However, in mat-form with straight fibres, the finished product is somewhat stiffer, as well as being less expensive. During the manufacture of the cloth, the fibres are sized as they are spun. This is to lubricate them for weaving and to bind them together in the cloth. The adhesion of resin to the glass is hampered by the presence of size, so it is often removed by heating, at 250-400 deg C, when it becomes a rich brown colour. Further heating makes the cloth white again, but it is detrimental to its mechanical properties.

TABLE I—EFFECT OF MOISTURE ON MECHANICAL PROPERTIES OF PAPER-BASED, LAMINATED SHEET

Condition	Equilibrium with 33 per cent relative humidity	Equilibrium with 75 per cent relative humidity	After immersion in water to constant weight
Tensile strength, ton/in²	12·6	10·4	7·6
Young's modulus, lb/in² × 10⁶	2·20	1·98	1·75

If it is essential that the finished product shall be white, the cloth should be used without de-lubrication. Solvents can be used to remove the size, but the results are not as good as those obtained by heating.

The best thickness range of the cloth for impregnation and laying-up is between 0·007 in and 0·009 in Loosely woven cloth is preferable on double curvatures as, in this form, it will more easily take the shape of the mould. The strength of the fabric lies along the warp and weft. With four-ply laminations, it has been found that the best all-round strength figures are obtained by laying-up the warp and weft alternately at 12-15 deg to a fixed line.

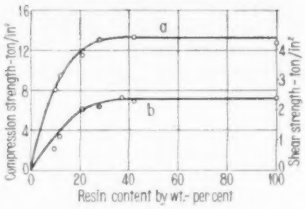
Design

The mistake most commonly made in the design of a plastics structure is to treat it in the same manner as a metal one. Plastics are in no sense a substitute for metal. They have different mechanical properties, and should therefore be treated differently. In order to save expense, components should be made in one piece as much as possible, for plastics lend themselves well to integral construction. In general, a skin thickness of $\frac{1}{16}$ in to $\frac{1}{8}$ in should be used. It can easily be reinforced locally, simply by employing additional laminations.

If very thick reinforcing sections are needed, timber may be moulded in. This is probably best because of the high price of plastics materials. If completely buried in plastics, timber or metal is completely protected from corrosion and other types of deterioration. Moreover, plastics materials will not readily support the growth of vegetable moulds or fungi. Apart from heavy reinforcement, thin sections of timber may be moulded in to take screws for the attachment of seats and other fittings.

Because of the low shear strength of plastics materials, the attachment of components, such as beams, is a difficult problem. However, this may be overcome by the insertion of local reinforcement at the attachment points. There are two ways of doing this, besides the method of inserting timber. One is to employ a wire mesh to strengthen the plastics laminations, while the other is to insert metal end fittings or flitch plates. As a result of the experimental work done at the Royal Aircraft Establishment, it has been found that fish-tail insertions between the laminations are the most efficient means of attaching lugs for bolts.

When sword-like blade inserts were used, it was found that, although excellent adhesion was obtained, and the failure was always in the Durestos, the average shear stresses developed were low. In a series of experiments, the glue was progressively omitted until only the last inch or so of the tip was glued. It was found that the actual failing loads of the inserts remained



a Compressive strength
b Shear strength parallel to laminations

Fig. 13. Shear and compression strength vary with resin content

the same irrespective of glue area, while the nominal stress in the glue increased greatly. From this it was deduced that, owing to the considerable difference in stiffness between Durestos and steel, almost all the load was carried at the tip of the fitting.

Because the thickness of a plastics panel is greater than that of a steel one, there is less likelihood of buckling occuring around large holes. Even greater stability can be obtained by employing a sandwich construction. This comprises two sheets of laminated plastics with relatively good mechanical properties, having between them an inexpensive, low-density, filling material. It is ideal for long compression members where lightness is of prime importance. There are several fillers available. One of these is Onazote, a hard, expanded ebonite compound.

It is only by handling sheets of Onazote that its remarkably light weight can be fully appreciated. It might be suitable for body floors as, in sandwich form, the strength/weight ratio is high and, over moderate areas, it needs no additional reinforcement in the form of stiffeners. Unlike most other sponge-like cellular compounds, its cells are not continuous. It is not attractive to vermin, and, in most cases, its water absorbtion, measured on a volume basis, is well under 2 per cent, after months of complete immersion. The material also has good thermal insulating properties. Its density can be as low as 4 lb/ft³, however, for most purposes a density of 8-10 lb/ft³ is recommended.

Another sandwich filler is Isoflex, a fabricated honeycomb material used for thermal insulation. This, or Onazote, would probably be most

useful for the sides and roofs of insulated trucks and vans, as well as for floor boards. However, over large floor areas, additional reinforcement in the shape of beams would, no doubt, be required. Other foamed plastics have also been developed for use as filling materials.

In view of the uni-directional properties of many laminated plastics, the orientation of the materials is important. This means that considerable thought must devoted to determining the nature and direction of the stresses likely to be induced in the structure. In general, body panels have considerable depth when employed as beams. For this reason, the stresses induced in them are light, so that they are unlikely to present any problems so far as plastics construction is concerned. An additional advantage of plastics is that the fatigue resistance is high. The booms, or flanges, of the panels may be reinforced with strips of Gordon Aerolite, which has a high compressive and tensile strength.

Because of the poor bearing strength of plastics, bolted and riveted joints should be avoided as far as possible. However, it is relatively easy to incorporate, in the moulding stage, any metal inserts needed to take the bearing loads. Glued joints are most satisfactory, and many suitable glues have been developed. One of these is Kaurite, a cold-setting glue, and another is Aerodux. Some authorities maintain that it is preferable to roughen the faces before gluing.

Pigment can be introduced into the resin to save the painting operation. However, more development work on this subject is needed. The materials so far produced have been rather translucent, so that the glass fibres show through, and spoil the appearance. The regular pattern of a finely woven glass cloth looks better, but it is still not as satisfactory as a coat of cellulose. Some manufacturers sand the surface before painting, while others do not.

So far, the problem has been treated as applied to the design of passenger cars. However, there are probably other applications for which plastics are possibly more desirable. Commercial vehicles used for certain purposes, for instance bakers vans, are particularly subject to corrosion. This problem would be overcome by the use of plastics. The thermal insulation of vans constructed of metal is an additional expense, and it is possible that by using a plastics material of sandwich construction, some economy could be effected. Components that are sometimes produced in small quantities, such as hard-tops for convertible bodies, might well be more economically made in plastics, as the tooling cost would not be anything like as great. Doors, bonnets, and boot lids made of these materials, possibly of sandwich construction, would be considerably lighter than those made of steel, and this construction might also eliminate trouble owing to drumming and rattling.

Bearings can be made of many plastics materials. Graphite impregnated, fabric-based phenolic, bearings are in many ways ideal for controls, as they do not require lubricating during use. Moreover, they do not pick up grit and dust in the same way as grease lubricated bearings. As an indication of the potentialities of this material, it is interesting to note that an aero engine with plastics bearings was run experimentally in Germany during the war. Layers of resin-bonded fabric were wound round and bonded to steel journals, and run in steel housings. The lubricant used was the normal engine oil, and it is claimed that the engine ran for over 200 hours at ratings up to 80 per cent of maximum output, without any appreciable deterioration of the bearing surfaces.

Two problems are of paramount importance in connection with plastics bearings. One is the removal of heat which might char the material, and the other is the problem of maintaining dimensional stability when used with liquid lubricants. Water is often an adequate lubricant with fabric or asbestos-based plastic bearings. This is probably because the fibres impregnated with water form a boundary layer similar to that formed by lubricating oil on metal.

Gears are often made of laminated plastic. For light duties graphite-impregnated material may be used, with no additional lubrication. Quiet running results from the high resilience of plastics which also gives improved resistance to shock loading and vibration. When a steel gear meshes with a plastic one, allowance must be made for the greater deflection of plastics as compared with steel. The tip relief must be modified to prevent the teeth of the metal gear cutting into the face of the other, when entering into engagement.

(To be continued)

TABLE II—STRENGTHS OF SOME LAMINATED PLASTICS AND METALS

	Specific gravity	Tensile strength (lb/in²)	Compressive strength (lb/in²)	Shear strength (lb/in²)	E (lb/in²×10⁶)	Specific: Tensile strength (lb/in²)	Specific: E (lb/in²×10⁶)
Durestos	1·27	15,250	13,000	5,000	2·0	12,000	1·57
Gordon Aerolite	1·43	70,000	34,000	2,000	2·0	49,000	1·4
Glass fibre (polyester)	1·82	43,000	42,000	8,000	3·0	23,600	1·65
Kraft paper (phenolic)	1·47	30,400	25,800	4,500	2·1	20,700	1·43
Duralumin	2·8	60,000	60,000	36,000	10·0	21,400	3·57
Mild steel sheet	7·8	45,000	45,000	22,000	29·0	5,800	3·7

Highly Heat-Resistant Paint

BY using silicone as a base for aluminium paint, a suitable protective finish may be provided for metal surfaces that are subject to great heat. Compounded specially for use on hot pipe lines, condensers, ovens, engine heads, silencers, radiators, exhaust manifolds, and similar surfaces that are ordinarily considered unpaintable, a special silicone-based aluminium paint, Heat-Rem H-170, produced by Speco Inc., Cleveland, Ohio, is said to withstand temperatures up to 1700 deg F. According to *Food Processing*, February 1952, the paint will dry within about 30 minutes of application, at room temperature without baking, and will fuse with surface metals to give a bright elastic finish that is resistant to moisture, corrosion, mild acids, and industrial fumes. (2013)

TURBO-COMPRESSORS*

Design and Operation of Exhaust-driven Units for Diesel Engines

By A. J. Penn, M.I.Mech.E.†

IN recent years the demand for four-stroke diesel engines of increased output for marine and traction purposes has resulted in the establishment of the turbo-charged power unit. Super-charging by means of the exhaust-driven turbo-compressor allows increased power output to be achieved without increase of engine capacity, and at the same time with improved overall thermal efficiency.

Diesel engines of the present day are operating continuously with a 50 per cent increase in power output by supercharging to between 4 and 5 lb/in^2 pressure. Increases in power output of over 100 per cent are being obtained on development by super-charging, but in this case charge-cooling is employed. In the future, turbo-charged four-stroke diesel engines should be operating in service at twice the power output of normally aspirated engines of the same capacity, and with lower specific fuel consumption. To meet the present requirements of the diesel engine industry, exhaust-driven turbo-compressors with a maximum continuous rating of 1·5:1 compression ratio are supplied, and for future requirements these units have been developed for a maximum continuous rating of 2·0:1 compression ratio.

This article describes the design and operation of such turbo-compressors for four-stroke diesel engines, and discusses the problems associated with matching these units on the engines to obtain optimum performance.

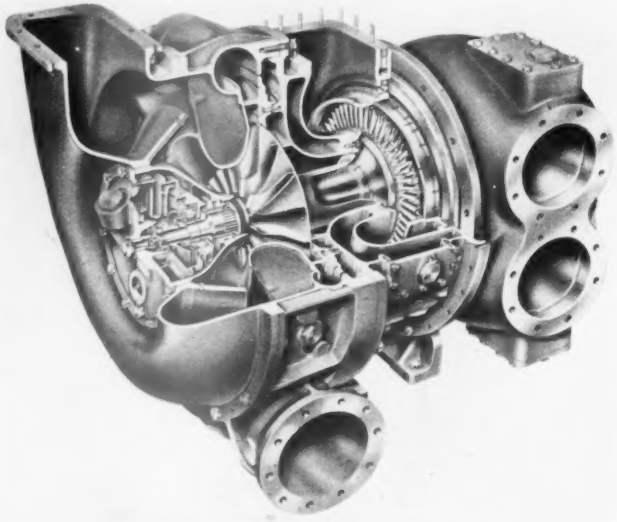


Fig. 1. Sectioned assembly of turbo-compressor unit

General description

A type of turbo-compressor suitable for universal application in the diesel engine industry has been designed and a series of basic units established to cover the wide range of engine outputs. This type of turbo-compressor comprises a single-stage centrifugal compressor driven by a single-stage axial-flow turbine, the rotary components being mounted on a common shaft. A sectional view of the unit is shown in Fig. 1.

To cover the range of outputs required for sensitivity of matching to ensure optimum engine performance, a number of basic sizes is chosen each having the maximum capacity range possible with one impeller and various diffusers. Each basic size has a ratio of maximum to minimum capacities of 1·6:1, which has been determined as a result of previous research and is illustrated in Fig. 2.

The turbine is designed so that its capacity can be matched to the minimum and maximum rated compressor capacities for a given basic size, to ensure the combined unit operating at the maximum overall efficiency without causing compressor surge, this being achieved by designing the nozzle assembly and rotor blades in such a manner that the blade height can be adjusted in standard increments.

To suit engines of different design, the compressor and turbine inlet casings are made so that they may be positioned at any angle to the turbine outlet casing which, in turn, may be set at any angle relative to the mounting feet. By this means any arrangement of engine induction and exhaust manifolding can be accommodated. The mounting feet are adjustable to allow the turbo-compressor to be installed in a position best suited to the engine.

For engines with different numbers of cylinders but of the same capacity, three types of turbine inlet casing with two, three and four entries are designed for each basic size; hence, by exhausting one, two or three cylinders into each manifold, one turbo-compressor can be employed for engines having from three to twelve cylinders. From the mechanical aspect the unit has been designed for long life, with ease in servicing and in the replacement of parts, and has its own lubrication system. The turbine casings are designed for water-cooling by fresh or salt water.

The impeller and turbine wheel are mounted on a common shaft carried in two resiliently mounted ball bearings. The bearings are located outside the impeller and turbine wheel to facilitate inspection and replacement *in situ*. Each bearing has self-contained lubrication by means of a disc-type oil pump mounted on the end of the shaft. Pressurized air sealing is incorporated in the rotor shaft assembly to ensure that the oil leakage from the bearings is an absolute minimum.

The compressor casings are made of sea-water-resisting aluminium alloy, and the impeller is machined from an aluminium forging. The turbine inlet and outlet casings are made of heat-resisting cast iron. The turbine wheel comprises a forged disc fitted with blading having fir-tree root type fixings which are a sliding fit in the disc, thereby ensuring a high degree of vibration damping. The disc and blades are manufactured

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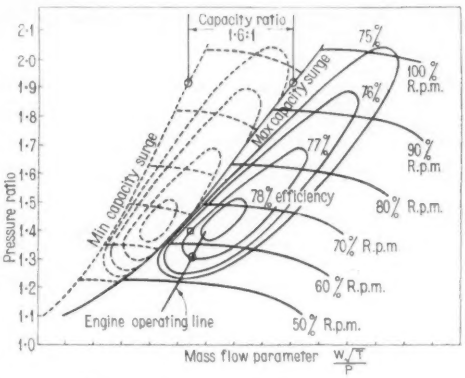
of high temperature steel.

The turbine wheel is stressed for continuous operation at a turbine inlet temperature of 600 deg C. and for operation at 650 deg C. for one-hour limited periods, relatively low stresses being employed to give long service life. On diesel engines with the unit operating at a pressure ratio up to 1·6:1 (one-hour limit rating), the maximum inlet temperatures experienced are in the neighbourhood of 500 deg C. to 550 deg C. The nozzle assembly consists of separate blades located in inner and outer rings. The inner ring is secured to the turbine inlet casing, and the outer ring is located axially but free to expand radially. The outer nozzle ring is partially slotted alternately from front and back edges to allow it to expand without distortion.



50 per cent supercharge case.
Matching : ○ Correct. □ Incorrect.
100 per cent speed quoted for 2·1 pressure ratio (Max. cont. operation)

Fig. 2. Typical compressor characteristics for a basic unit

Design of centrifugal compressor

The centrifugal compressor comprises a single-sided impeller in an aluminium-alloy casing containing a fixed vane diffuser. Two forms of air intake are available; one of the axial type incorporating a filter-silencer for inhaling air from the immediate surroundings, and the other a single-entry volute type for use when ducting is employed. The delivery is arranged in the form of a spiral volute with a single discharge.

Air inhaled enters the impeller near its axis, as shown in Fig. 3, and while flowing out through the impeller it is given high tangential velocity. The air then enters the diffuser in a spiral path between the fixed vanes in which the kinetic energy imparted to the air is converted into pressure with rapid reduction of velocity. The air leaving the diffuser passes through the delivery volute to the engine induction system.

The impeller has straight radial vanes which are given a degree of curvature at the entry in order that the air may enter the impeller with minimum pressure loss. The velocity diagram at impeller entry is superimposed on Fig. 3.

The tip speed for the compression ratio required has to be determined and the diameter fixed in relation to the overall dimensions of the unit and the maximum safe rotational speed for the required degree of mechanical reliability. The entry diameter for the impeller is decided in relation to the Mach No., which should be a minimum for optimum efficiency, and it is preferable for the diameter to be slightly larger than the optimum. The number of blades selected is a compromise; a large number reduces the separation between blades but results in restriction of entry to the impeller with resultant high pressure loss. The area at the periphery of the impeller should be as small as possible provided that it does not result in too large a spiral angle. The velocity diagram and spiral angle at the periphery of the impeller resulting from the effect of the relative eddy velocity, but not from separation, is given on Fig. 3.

The tangential component leaving the impeller, for the radial blade type, is less than the peripheral velocity due to relative eddy. The angle of the air leaving the impeller is determined from the tangential velocity and the mean radial velocity. The radial distance between the impeller and diffuser entry is usually set at approximately 0·05 of the impeller diameter, and the outside diameter of the diffuser at 1·4 of the impeller diameter. These ratios have been established as a result of compressor research. The number of blades for the diffuser is decided as a result of previous experimental data and in relation to the spiral angle of the air entering the diffuser. The vanes approximate to an aerofoil section and the forward portion is designed to follow the spiral angle curve up to the throat formed by two adjacent blades. From this point the vane contours are designed with a certain degree of divergence from the spiral angle curve in order forcefully to divert the air

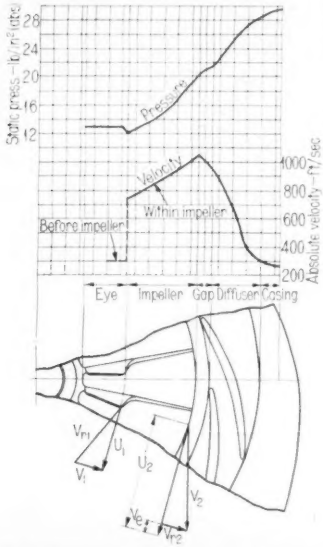


Fig. 3. Pressure and velocity changes through the centrifugal compressor

SYMBOLS—COMPRESSOR

V_1	Axial velocity entering impeller
V_2	Absolute velocity leaving impeller
U_1	Peripheral velocity at eye tip
U_2	Peripheral velocity at impeller tip
Vr_1	Relative velocity at eye tip
Vr_2	Relative velocity to impeller tip
Ve	Relative eddy velocity

SYMBOLS—TURBINE

Va_1	Axial velocity at rotor inlet
Va_2	Axial velocity at rotor outlet
C_1	Absolute velocity at nozzle outlet
V_1	Relative velocity at rotor inlet.
U	Peripheral velocity of rotor
β_1	Rotor inlet gas angle
α_1	Nozzle outlet gas angle
Vw_1	Whirl velocity from nozzle outlet
V_2	Relative velocity at rotor outlet
C_2	Absolute velocity at rotor outlet
β_2	Rotor outlet gas angle
S	Outlet swirl angle
Vw_2	Outlet whirl velocity

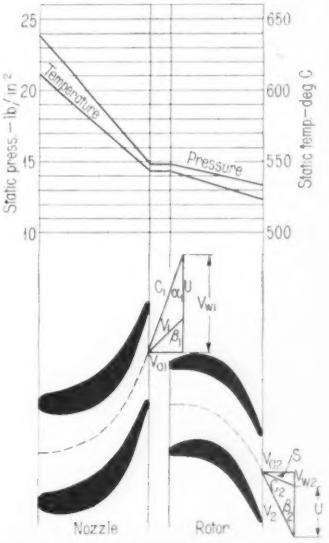


Fig. 4. Pressure, temperature and velocity changes through the axial-flow turbine

from its free spiral path and so to hasten the transformation of kinetic energy into pressure. The design of blades at exit is such that the velocity of the air leaving the diffuser is reduced to within 200 to 300 ft/sec. Typical pressure and velocity changes of the air passing through the centrifugal compressor are shown in Fig. 3.

Design of turbine

The axial-flow turbine comprises a single row of nozzle guide vanes and a rotor wheel with impulse blading. To avoid return flow of the exhaust gases to adjacent manifolds, certain of the nozzle guide vanes mate with the dividing walls in the intake casing. In designing the turbine the gas mass flow is assumed to be equal to the air mass flow of the compressor, and to determine the expansion ratio a pressure drop across the engine is assumed; the mean turbine inlet temperature is determined from the diesel engine cycle. Since the compressor power input is equal to the turbine power output, the total head temperature drop across the turbine can be derived. Using these data the turbine blading is designed on the free vortex theory in which the angular momentum is assumed constant at all radii, and to satisfy this the swirl velocity varies inversely as the radius, and the axial velocity and work output are constant over the annulus.

Turbine blading for impulse conditions has all the available pressure energy converted into kinetic energy in the nozzles. As the blading is designed on the free vortex theory, impulse conditions exist only at the root where the pressure drop across the rotor blade is zero. Up the height of the rotor blading the pressure drop increases progressively to the tip to establish radial equilibrium.

For the basic turbine the nozzles and rotor blades are designed with constant annulus height. To obtain the actual blade angles the conditions at the root are first established. The nozzle outlet angle is chosen to be in the neighbourhood of 20 deg and from this, and the absolute velocity corresponding to the design expansion ratio, the axial velocity at exit is determined. Since this axial velocity is held constant, the annulus height can be established. Having determined the annulus height, the axial velocity at entry to the nozzles is derived and is between 400 and 500 ft/sec. The rotor blade inlet angle is determined from the rotational speed and the nozzle exit velocities by means of the usual velocity triangles. The rotor blade outlet angle is determined from the necessary reduction in whirl component, rotational speed and the axial velocity at exit by means of velocity triangles. Swirl angles above 15 deg and high absolute leaving velocities are avoided in the design to minimize the pressure losses in the delivery chamber, and hence ensure maximum total head expansion ratio. Typical velocity triangles and pressure and temperature changes in the gas passing through the nozzle and rotor blading at mean blade height, are shown in Fig. 4.

Static cascade tests have established that passage shape between adjacent blades is the important design criterion and therefore, having established the gas angles, the blade sections are constructed to form convergent passages in accordance with research data. To ensure high efficiency over the operating range of the turbine some incidence on to the rotor blading is allowed for in the design conditions and therefore the blade angles differ slightly from the gas angles derived from the velocity triangles.

Matching unit to diesel engine

The choice of a turbo-compressor unit for a specific engine is made by considering details of the engine type, capacity and rating; using these data, the basic size of unit, the diffuser and the turbine blade height are selected and the manifolding arrangements recommended.

In deciding the free air capacity required, an air quantity in excess of the swept volume of the engine is allowed for scavenging purposes, this excess being 35 per cent for the 50 per cent supercharge rating. To obtain this air consumption with the recommended valve timing a boost pressure of approximately 4·5 lb/in² is required and therefore a compression ratio of 1·3:1 is necessary from the compressor for the 50 per cent supercharge rating. As a result of many tests on different types of engines it has been established that under these conditions good economy and relatively low cylinder exhaust temperatures are obtained.

From these derived data the basic size of turbo-compressor and diffuser are selected. The actual capacity of the turbine within this basic size of unit is determined in relation to the compressor performance characteristics and is selected to give maximum compressor efficiency for surge-free conditions over the engine operating range. This is illustrated in Fig. 2.

In recommending the manifolding for a specific type of engine, it is important to realize that the satisfactory performance obtained with low boost pressure on a turbo-charged four-stroke diesel engine is mainly due to the fact that the high energy exhaust pulses obtained at exhaust release are utilized. It is therefore essential to arrange the manifolding so that the exhaust pulses from each cylinder do not interfere with the pulses from the other cylinders and thereby reduce their effect and impair the scavenging of the cylinder. When turbo-charging four-stroke diesel engines to achieve the required excess air ratio, an increased overlap is necessary. The valve timing normally recommended for turbo-charged diesel engines is shown in Fig. 5. During the overlap period the pressure in the exhaust manifold must be less than the charging pressure to obtain effective scavenging and to ensure that a minimum of residual exhaust gases is trapped in the cylinder. Ideally, one manifold per cylinder

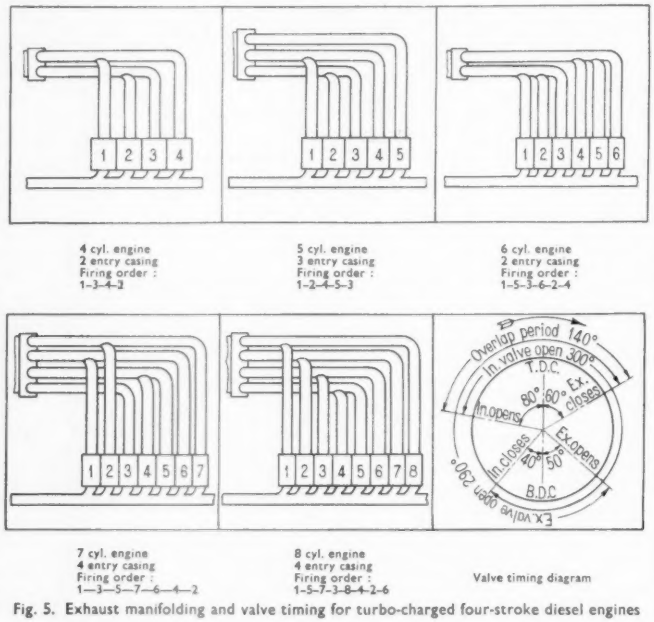


Fig. 5. Exhaust manifolding and valve timing for turbo-charged four-stroke diesel engines

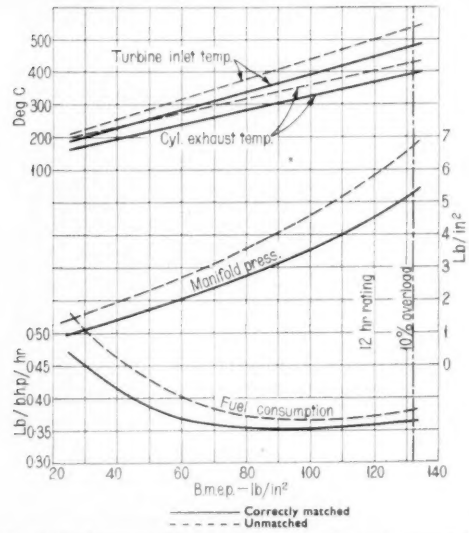


Fig. 6. Performance of four-stroke diesel engine with incorrectly and correctly matched turbo-compressors

should be employed, but to reduce manifold complications and turbine annulus size it is usual to arrange that two or three cylinders discharge into one manifold and connect with one of the inlets of the turbine inlet casing which is an independent passage right up to the turbine nozzle. The maximum number of cylinders that can be discharged into one manifold is three. Where two or three cylinders discharge into one manifold the cylinders must be selected in relation to their firing order so that the points of exhaust opening are evenly spaced over two crank revolutions. In the case of three cylinders discharging into one manifold the exhaust valve of one cylinder will open approximately 40 deg crank angle before that of another cylinder of the group closes; this alters the pulse configuration in the manifold, but in practice it has been found that this effect can be tolerated.

For four- and six-cylinder engines two manifolds are normally recommended; for five- and nine-cylinder engines three manifolds are recommended; and for seven- and eight-cylinder engines four manifolds are recommended. An illustration of the different manifolding in relation to cylinder firing order, and the appropriate turbine inlet casing required, is shown in Fig. 5.

During initial engine trials with the recommended size of turbo-compressor and type of manifolding, test data are obtained. From analysis of these data it can be ascertained whether or not the turbo-compressor is correctly matched to the engine. Should the matching be incorrect the turbo-compressor will either be running at too low a speed and supplying too low a boost pressure, or running at too high a speed and supplying too high a boost pressure; in either case this will adversely affect the engine performance and the overall specific consumption of the engine. In view of the wide operating characteristics of the centrifugal compressor, mismatching can generally be corrected by a change of turbine capacity. The turbo-compressors are so designed that this change of turbine capacity can be made on site and within a matter of hours. An example of the effect of mismatching a turbo-compressor unit in relation to a diesel engine is shown in Fig. 6. In this figure curves are given for a case where the turbine is unmatched, and it can be seen that for the 100 per cent load condition (50 per cent supercharge) a boost pressure of 5·75 lb/in^2 and a cylinder exhaust temperature of 400 deg C. are obtained, the specific fuel consumption being 0·375 lb/b.h.p/hr.

Referring to Fig. 2, it is apparent that in this case the engine operating point is too close to surge and therefore an increase in turbine capacity is necessary; the degree of increase in capacity can be assessed in relation to the compressor characteristics. Fig. 6 shows the performance obtained after the turbo-compressor has been correctly matched to the engine, and that the boost pressure has been reduced by 1·25 lb/in^2 to 4·5 lb/in^2, the cylinder exhaust temperature by 35 deg C. to 365 deg C., and the specific consumption by 0·025 lb/b.h.p/hr to 0·350 lb/b.h.p/hr. There is also a corresponding drop in turbine inlet temperature but this is not so important because the turbine is designed for a maximum temperature which is well in excess of the operating conditions at present experienced on diesel engines.

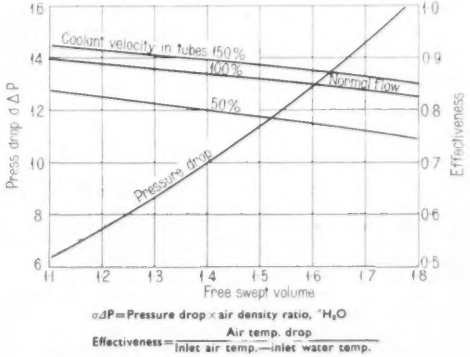
It will be apparent that correct matching of the turbo-compressor to the engine is extremely important, as although both the engine and turbo-compressor may be efficient individually, the overall performance obtained can be poor if they be unmatched. Once a certain type of diesel engine has been correctly matched with a turbo-compressor, unless there is a change of engine rating, individual matching of other engines of the same type should not be necessary.

Factors affecting supercharging of diesel engines

Satisfactory turbo-charging of four-stroke diesel engines depends on certain main limitations and factors, and the effect of these can be accentuated by the ambient conditions prevailing.

The limitations are engine exhaust valve temperature and maximum cylinder pressure, which limit the degree of supercharging. Supercharging can, however, be increased within the engine exhaust limitations by charge cooling, in which case the limitation tends to become mechanical loading and consequently b.m.e.p.

The factors affecting performance are variations of ambient pressure, temperature and humidity, inlet and exhaust valve timing, type of combustion chamber and the arrangement of induction and exhaust manifolding between the engine and turbo-compressor. The variations of ambient conditions are important factors where an engine is required to operate at altitude or in the tropics, as under these conditions a lower output is obtained unless the standard exhaust valve temperature of the engine is exceeded. The valve timing must be arranged to give sufficient overlap of inlet and exhaust valve opening periods to ensure satisfactory scavenging and reduction of exhaust temperature, see Fig. 5. The other two factors mentioned can have adverse effect on the performance if not given careful consideration in the initial design.

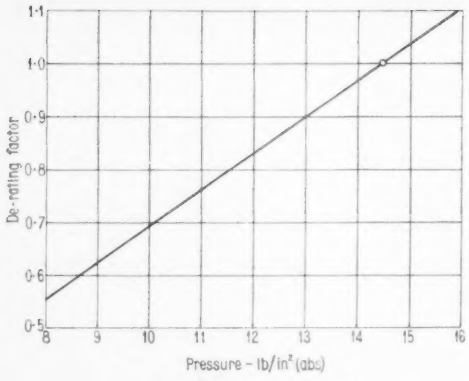


$d\Delta P$ = Pressure drop × air density ratio, "H_2O

$$\text{Effectiveness} = \frac{\text{Air temp. drop}}{\text{Inlet air temp.} - \text{inlet water temp.}}$$

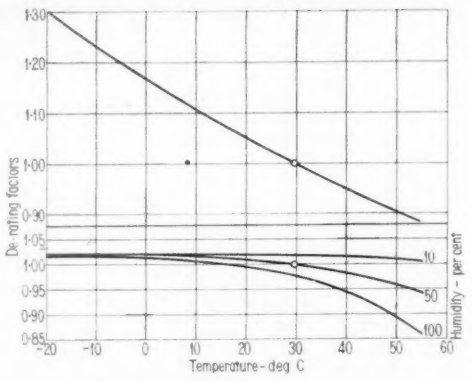
Fig. 7. Characteristics of water-cooled charge-cooler

Charge-cooling, which has recently been introduced to permit increased



Based on B.S.I. standard conditions : 29.5 Hg (14.45 lb in_2 absolute)

Fig. 8. Power output corrections for variation in ambient pressure



Based on B.S.I. standard conditions : 29.4 deg C. (85 deg F.) and 50 per cent humidity

Fig. 9. Power output corrections for variations in ambient temperature and humidity

supercharging in order to obtain higher outputs, has shown to particular advantage, since the increased outputs have been obtained without adverse effect on specific fuel consumption. For each basic type of turbo-compressor unit a water-cooled charge-cooler is available having an effectiveness of at least 70 per cent and is designed so that it can be installed between the turbo-compressor and the induction manifolding. Fig. 7 shows the typical performance of a water-cooled charge-cooler used in conjunction with turbo-compressors.

Turbo-charged four-stroke diesel engines have world-wide application for stationary, marine and traction purposes and therefore the effect of prevailing atmospheric conditions on performance must be assessed when deciding the engine rating. Variation in atmospheric pressure affects the output in direct proportion to the absolute value. Variation in temperature affects the power output as an inverse function of the absolute temperature.

Humidity variations affect the engine output as a direct function of the partial pressure of the water vapour. Corrections curves for the effect of atmospheric conditions on engine power output are given in Figs. 8 and 9.

A turbo-charged traction engine operating under conditions of 4,000 ft altitude at a temperature of 40 deg C. with a humidity of 50 per cent would have an output 18 per cent lower than the standard B.S.I. rating if the established cylinder exhaust temperature is not to be exceeded. Therefore, for such an application, an engine must either be de-rated or allowed to operate at a cylinder exhaust temperature higher than for that of the standard B.S.I. rating. The standard B.S.I. conditions for rating purposes are 29·5 in Hg (14·45 lb/in² absolute), 29·4 deg C. (85 deg F.), and 50 per cent humidity (15 mm Hg vapour pressure).

Trend of future development

It is anticipated that the trend of future development in the four-stroke diesel engine field will be towards the introduction into service of turbo-charged engines with power outputs twice those of normally aspirated engines of the same capacity. In view of this a new series of turbo-compressors has been developed for a maximum continuous rating of 2·0 : 1 pressure ratio and these are now available to the industry together with suitable charge-coolers.

In the two-stroke diesel engine field a number of systems of supercharging by means of turbo-compressors are at present being tried, including various versions of the parallel and series systems incorporating mechanically driven compressors with the object of obtaining satisfactory starting and low output operation. The inherent difficulty in turbo-charging two-stroke diesel engines is the fact that until a certain engine speed and power output are reached the turbo-compressor is not self-supporting. The trend of development in this field would appear to be the establishment of a supercharging system incorporating a turbo-compressor in which a reasonably simple installation is obtained and good performance over the operating range achieved with a high standard of mechanical reliability.

HARDENING GEAR TEETH

FACED with the problem of hardening the teeth of gears to 52 Rc while maintaining a core hardness of only 36 Rc, the Yale and Towne Co., Philadelphia, has developed a semi-automatic method of selective heating in a salt bath. Overall heating, induction hardening and flame hardening had been tried but found liable to cause burning, overheated tooth tips and scaling. Scaling necessitated sand-blasting which lowered wear resistance. Distortion up to 0·005 in. was encountered and excessive quenching stresses resulted in a high percentage of rejects.

The method adopted is described in the November 8th, 1951, issue of *Iron Age*. Gear blanks are first normalized and annealed to 195-200 B.H.N. and then rough cut and hardened all over to 36 Rc. After sandblasting, the bores are splined to finished size and the face and teeth are machined.

Four gears are locked on a shaft mounted on a simple fixture above the salt bath into which the teeth dip. An electric motor rotates the shaft at a speed of 40-45 r.p.m. for a period of four minutes, by which time the teeth acquire the bath temperature of 1,525 deg F. The gears are then quenched at 150 deg F. and finally tempered for 45 min at 430 deg F.

In the result the teeth are uniformly hardened to 52 Rc, there is no scale, and distortion is minute but favourable. Actually, the hub of the gear closes slightly—less than 0·001 in—indicating a desirable state of compression. A simple broaching operation restores the spline dimensions.

The rate at which the gears are rotated is a compromise between a high speed that would throw salt out of the bath and a slow speed that would allow the teeth to cool while exposed to the air. At about 45 r.p.m. the carry-out of salt is sufficient to maintain the temperature of the teeth between immersions and to protect them from the atmosphere. (2008)

FILTRATION

A Survey of Methods for Maintaining Engine Cleanliness

By W. J. Burnell*

THE technique of engine protection by filtration has grown hand in hand with the motor industry but a clear understanding of the subject is often either eclipsed by bigoted commercial partiality or obscured by the intricate postulations of the specialist. Accordingly, it is intended here to take a middle course between these extremes in the hope that readers, desirous of attaining a critical understanding but unfamiliar with the specialist aspects of the subject, will benefit.

Lubricating oil filtration

Firstly, there is the question of lubricating oil filtration in automobile engines. Oil becomes contaminated in three ways, namely, residual dirt left in the engine during manufacture, products of oil deterioration, and finally, dust entering via the carburettor intake. The removal of these contaminants may be performed by means of two basic systems of filtration—by-pass or partial flow, and full-flow filters. In view of the old controversy surrounding the relative merits of these two systems, it is necessary, for the sake of continuity, to digress a little to describe them. In the so-called full-flow system, all of the oil circulating (with the exception of the portion shunted back to the sump via the oil pump relief valve), is filtered continuously. It is evident that if such a filter succeeded in removing all of the contaminant during a single pass, there would be no argument about the superiority of the full-flow system. In practice however, this ideal is for many reasons not attained.

The filter media must be chosen for its high permeability to oil as much as for its intrinsic filtering characteristics, if excessive pressure loss is to be avoided. A by-pass valve must in any case be included, designed to open at some predetermined critical value. It will be appreciated that the pressure drop is a function of the formation of a filter "cake" on the media itself, thus towards the end of its life, when the by-pass valve is shunting oil direct to the main oil gallery, the full flow filter performs the duty of an inferior sort of partial flow filter.

It will be evident that full flow filters can usually only be fitted at the motor manufacturer's works in conjunction with the engine designer, for special arrangements must be made to lead the oil from the pump through the filter and thence into the distributing gallery.

A by-pass filter operates by drawing off oil at some suitable point in the high pressure side of the system (the pressure gauge is often chosen for this purpose), and after cleaning, the effluent is returned direct to the sump. The flow of oil is controlled by a restrictor so that only a portion of the oil normally returned to the sump through the pump relief valve is actually filtered, thus the inclusion of a by-pass filter in no way debilitates the efficiency of the lubricating system.

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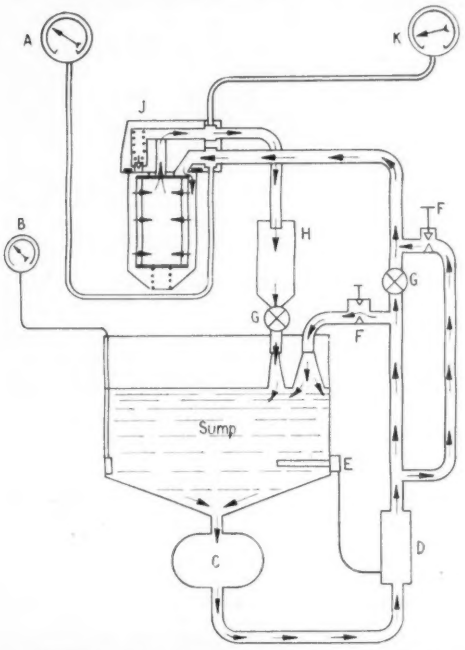
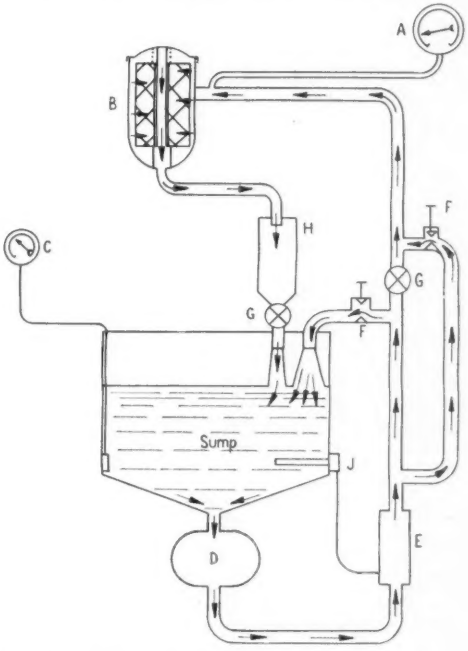


A Inlet pressure gauge B Thermometer C Pump D Heater
E Thermostat F Needle valve G Gate valve
H Measuring can J Filter K Outlet pressure gauge

Fig. 1. Diagrammatic arrangement of full-flow filter test rig



A Inlet pressure gauge B By-pass filter C Thermometer D Pump
E Heater F Needle valve G Gate valve H Measuring can

Fig. 2. Diagrammatic arrangement of by-pass filter test rig

The rate of cleaning is adjusted to overtake the rate of contamination by a considerable margin in order to maintain the oil in a clear condition at all times. In practice, however, this does not necessarily mean that the engine is fully protected at all times, for the very fact that only a portion of the circulating oil is actually filtered at any one time, means that under some emergencies, heavy contamination might reach vital parts of the engine before being finally captured by the filter.

Moreover, the oil is usually drawn off at a port with its axis perpendicular to the oil gallery. Consequently, excessively large and heavy particles carried along in the main stream, by reason of their kinetic energy, are not easily diverted into the secondary circuit and in fact may fail to enter it at all. It is beyond the scope of this article to treat the controversy exhaustively, but in order to provide some data for the argument, a simple experiment was carried out to compare the relative cleaning performance of various filters.

Comparisons were made between a felt full-flow filter of a well-known make, a Fram paper element full-flow filter and a Fram by-pass "depth" cotton filter. These filters were all of standard

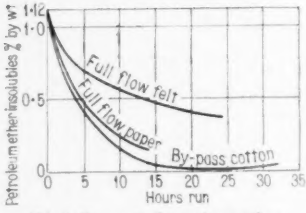


Fig. 4. Removal of petroleum ether insolubles

type, designed for use in conjunction with a particular make of engine.

The full-flow filters were each in turn connected in an oil circulating system similar to that provided in service, except that refinements were included to facilitate the control of specified test conditions. The test rig

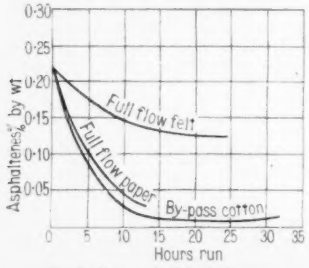


Fig. 6. Removal of Asphaltenes

is shown schematically in Fig. 1. The sump was filled with 1½ gallons of dirty oil stock of known constitution, and the differential pressure across each filter was adjusted to give a flow of 100 gallons per hour at a temperature of 80 ± 2° C.

A one pint sample was withdrawn from the sump every hour for solids determination by centrifuge, the sump

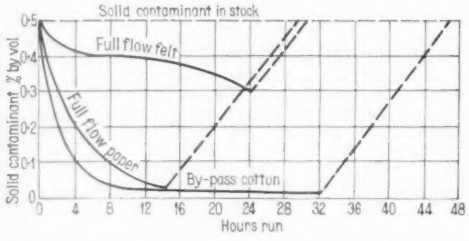


Fig. 3. Filtration in terms of "solids" (as a percentage by volume) with time

contents being made up with a pint of dirty oil stock. Every third sample was retained for determination of Benzene and Petroleum Ether insolubles. These operating conditions were maintained until the differential pressure attained a maximum of 12 lb per sq in when the filter was considered to be exhausted.

The by-pass test rig is shown in Fig. 2. For obvious reasons, the test conditions must differ from those laid down for full-flow, but are once again representative of actual running conditions on the vehicle. The sump was filled with 1½ gallons of the same dirty oil stock. An oil pressure of 50 lb per sq in at 80 ± 2° C. was maintained at the inlet port and the sampling procedure previously described was again followed. The test was continued until the sump contamination began to rise, when the filter was considered to be exhausted.

Before discussing the results, it may be of interest to those unfamiliar with oil analysis to expand a little on the significance of the terms Benzene and Petroleum Ether insolubles. Such is the complexity of mineral oil and its deterioration products that it is not possible to express the constituents at individual entities, and for this reason groups of hydrocarbons are selected and identified under various headings.

For our purpose, only a few of these groups are considered; firstly, Petroleum Ether insolubles, which give an indication of all the oil insolubles, plus oil soluble and insoluble asphaltenes, together with other deterioration products. Included under this heading are all solids both organic and inorganic.

Secondly, Benzene insolubles, which include only inorganic solids and insoluble carbonaceous products. Thirdly, Asphaltenes, which are oxydation products of a resinous nature, brownish black in colour, hard and brittle when cold, gummy at elevated temperatures. In addition, there are many other groups and sub-groups, but in the interests of space and simplicity they have been ignored, suffice to say that the groups mentioned have a very real significance in engine deterioration.

The insolubles determination and centrifuging technique were carried out in accordance with those prescribed by the Automobile Research Committee of the Institute of Automobile Engineers[1].

Fig. 3 shows the progress of filtration in terms of "solids" (expressed as a percentage by volume) with time. The term solids in this instance refers to all of the stratified matter lying beneath the clear liquor in the vessel after centrifuging, strictly, therefore, it includes liquids as well. The paper, felt and cotton filters were exhausted after approximately 14, 24 and 32 hours respectively.

The plots have been extended from the points of exhaustion by dotted lines sloping in accordance with the contamination rate (one pint of stock per hour), in this way a more realistic picture of the relative duty of each type of filter is produced. Thus, it will be observed that whereas the felt

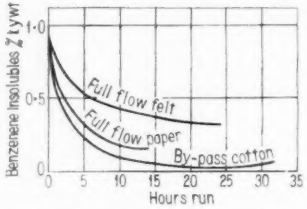


Fig. 5. Removal of benzene insolubles

media apparently gives a long life in comparison with the paper, the actual contamination never falls below 0·3 per cent and moreover, the plot extensions show that the sump contamination would rise to its original value at about the same time for both filters i.e. 30

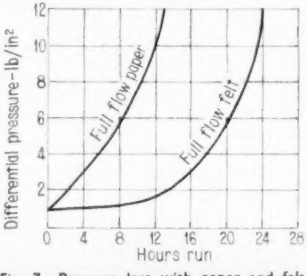


Fig. 7. Pressure loss with paper and felt full-flow filters

hours after the commencement.

Diminution of contaminant is much more rapid for both the paper and cotton filters than for the felt. The effective life of the paper and felt filters is about the same if intrinsic cleaning characteristics are ignored, but the life and cleaning properties of the "depth" type by-pass filter appear to be incomparably better. In fact, the plot demonstrates the immense advantages of filtration in depth. It might be argued that the test conditions being different it is illogical to make such direct comparisons, on the other hand it must be remembered that the tests simulate actual field running conditions and therefore, it is certainly pertinent to consider the performance figures as a whole.

Figs. 4, 5 and 6 serve to indicate the progress in cleaning in terms of Petroleum Ether and Benzene insolubles and Asphaltenes respectively. Fig. 7 shows the pressure loss with time for the two full-flow filters. Examination of these plots in conjunction with Fig. 3 seems to indicate that for the first twelve hours, a filter cake is being built up on the felt media, after which the finer contaminant is retained more readily. Fig. 8 indicates the flow against time for the by-pass filter.

The high performance of depth filters has been observed by car users, who have often remarked on the clear oil condition achieved. However, for the reasons already stated, it is unsafe to conclude from this evidence alone that the partial flow is superior.

It follows that both systems make a definite contribution. Probably the full-flow filter serves its most useful purpose during the early stages of engine life when large particles of manufacturing residuals are prevented from circulating. Later, when oil deterioration products abound and fine particles of dust have accumulated in the crankcase (having entered with the carburettor air), the partial flow filter is, without doubt, the more effective.

The effects of fine abrasive dust in carburettor air have been investigated exhaustively in America by W. S. James, B. G. Brown and B. E. Clark[3], who made an extended series of observations both under actual road conditions and in conjunction with a specially constructed dust tunnel. Of particular interest in this article are the results of a test showing the effect on bore wear of an engine running in an atmosphere of abrasive dust, protected in turn, with by-pass and full-flow filtration.

In Fig. 9 the bore wear is shown increasing from left to right. Measurements were taken at the top and bottom dead centres of the top and bottom ring travels. The by-pass system, under these particular conditions, appears to achieve greater protection.

In the main, all the tests carried out suggested that efficient by-pass filters afforded greater protection against engine wear, for similar results were obtained for piston ring gaps, main and connecting rod bearing clearances and crankshaft diameters—crankpins and journals. However, for the reasons given formerly, it would seem logical to conclude that for optimum cleaning efficiency, both systems should operate at one and the same time.

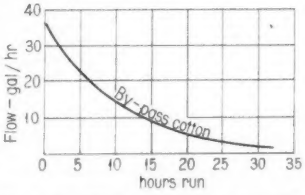


Fig. 8. Flow/time curve for a by-pass filter

Filter media

Up to this point, little has been said concerning the choice of media for each system. The materials used in filtration are many and to keep the matter within reasonable compass, only a few basic ones have been chosen for discussion. At present two materials find favour in full-flow filtration for motor-car engines — wool felt and paper. In order to comply with the premise, high permeability to oil, the material must be relatively "open" by nature, but shall at the same time capture and retain the smallest reasonable particle.

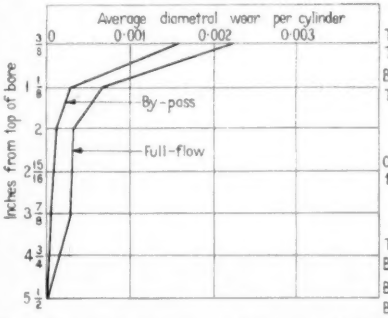


Fig. 9. Comparative bore wear with by-pass and full-flow filtration

A great deal of doubtful information has been published about this and that media. It is not unusual, for instance, for a claim to be made that a certain filter has a definite shut-off characteristic in that all particles larger than a specific minimum will be captured and retained. Such claims would be difficult to validate in practice, for when dealing with fine particles, an astronomical number of size frequency determinations are necessary to qualify the result in scientifically acceptable terms. Combined with this objection is the effect on pore size of the filter cake itself, resulting in a continuous modification to the shut-off point immediately the determination is attempted.

In brief, a satisfactory full-flow media is best described as a sieve, the sieving action being modified with time by the lodgement of particles large enough not to pass through the mesh, thereby producing smaller pores, smaller and smaller particles being captured as the decreasing voids are filled.

The filter paper used in the experiment described above, was made from pure cotton linters, giving a fine homogeneous "mesh" of only moderate strength. As delivered from the mill, it is unsuitable for immediate use as a filter media and must be strengthened by suitably impregnating, usually with a thermo-hardening resin. The resin must be chosen carefully and applied in a special manner in order to avoid uncontrolled modification to the pore structure.

In partial-flow filtration the designer is less restricted in his choice of media because a high pressure differential is not only possible, but by definition, necessary. For this reason, advantage may be taken of this adsorption phenomena.

Adsorption is a function of the mutual surface activity between the filter media itself, and the particles in contact with it. The origin of the forces involved is not precisely known, possibly they stem from the attraction of unlike electrical charges on the particles and media respectively. T. C. Worth's[5] experiments tended to support this view. He showed that at a pressure drop of 8 lbs per sq in across a given depth of matt fibres, an e.m.f. of +15 volts was generated. Negative e.m.f.s were manifested at higher pressure differentials.

The writer has for some time been associated with experiments to determine the adsorping power of many varieties of fibrous material, but at the time of writing, cellulose fibres appear to have the greatest capacity.

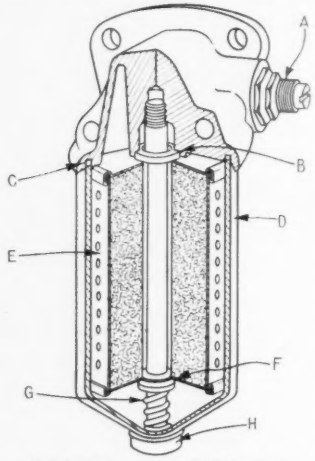
An interesting demonstration of the relative adsorbtive powers of various fibres was undertaken by C. A. Rodman and A. W. Pansey[4]. By utilizing microscopic technique, they appear to have reached the same conclusion, i.e. cellulose, in the form of cotton fibres or as paper, were superior to all others investigated.

The adsorptive power of fibrous materials may be enhanced by impregnating with a coagulant such as triethanolamine which has been used

successfully in the Fram by-pass filter. Other alkylolamines have been suggested as being equally efficacious. These substances are relatively immiscible with oil and are retained by capillary attraction in the fibres, and serve to coalesce and engulf even colloidal matter. They also have the power of combining with many acids existing in oxidized oil.

The dimensions of a filter of the adsorption type must be chosen with care to ensure that the fluid velocity is commensurate with the forces set up in the media itself. If the velocity is too high, the particles may relinquish their hold on the media surface.

Effluent from such a filter is seen to be quite clear and free from extremely fine particles which, but for the adsorption activity, would pass quite easily through the natural voids of the pack. Essentially, if full advantage is taken of adsorption phenomena, the media must be used in depth. This gives rise to difficulties in manufacture, where agglomerations of the fibres may occur resulting in corresponding channels elsewhere in the pack. Given a homogeneous fibre mass, however, it may be said that a depth type filter is unsurpassable for engine



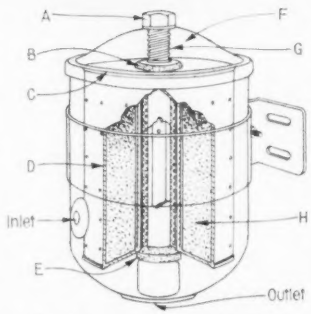
A Relief valve — B Top sealing washer
C Cover gasket — D Body
E Cartridge — F Bottom sealing washer
G Spring — H Centre bolt

Fig. 11. Another typical by-pass filter

oil lubrication. Space limitations rule it out for full-flow work, where low pressure loss is essential.

Figs. 10 and 11 are sectional views showing the construction of typical by-pass filters. The oil passes from the outside to the inside of the element and passes out at the bottom. The type shown in Fig. 10 may be fitted to almost any class of vehicle, and connected to the oil system by means of suitable unions and pipelines supplied by the filter manufacturer.

Fig. 11 shows a similar filter suitable for fixing direct to the engine at



A Cover bolt — B Centre tube washer
C Top cover gasket — D Cartridge
E Centre tube washer — F Cover
G Spring — H Cotton filtering media

Fig. 10. A typical by-pass filter

a suitable abutment adjacent to the main oil gallery, no pipework being necessary. It will be noted that the oil pump relief valve has been embodied in the filter head casting.

The replacing of exhausted elements is made easy by removing one bolt only, when the cover or body may be slipped off with facility. Fig. 12 illustrates a typical full-flow filter. Once again, the element change is easily performed necessitating the removal of one bolt.

Cooling system protection

At the present time, internal combustion piston engines succeed in converting only about 30 per cent of the fuel heat into useful power, a little more than half the surplus heat escapes through the exhaust, and the remainder, say 30 per cent or so, is disposed of by the cooling system.

Not only is the amount of heat large, but at some surfaces in the engine it must be extracted at very high temperatures. For example, at cruising speed the temperature in each cylinder rises to somewhere in the region of 4500 deg F about 30 times a second and must be reduced to about 1200 deg F at the same rate. It is clearly necessary for the cooling system to be maintained at peak efficiency continuously to avoid excessive internal temperatures resulting in engine damage.

Simple as the cooling system is, it

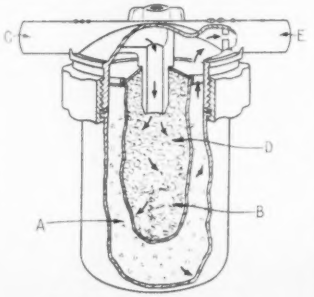


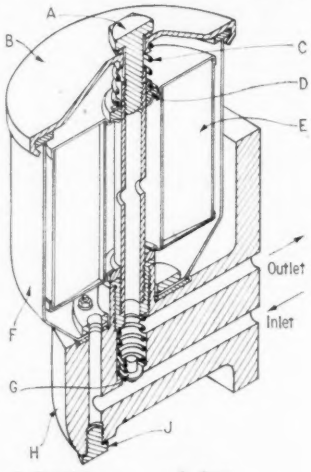
Fig. 13. Cooling system filter

suffers in practice from two serious maladies, namely, corrosion and scale formation, both of which are due to characteristics of the coolant itself.

Rusting and other forms of corrosion are accelerated at high temperatures and encouraged by water having a low *p*H value (rich in hydrogen ions). Where unlike metals are in contact with water of low *p*H, the system becomes, in effect, a complex weak galvanic cell giving rise to electrolytic corrosion. The results of corrosion are many and manifest themselves in chokes, leaks and other tribulations well-known to the motorist.

Scale formation is brought about by reason of the dissolved minerals—always present in public water supplies—precipitating on hot surfaces. Calcium carbonate is the most important mineral constituent of the chalky "cake" usually found in hot water and cooling system. This scale, being a very poor transmitter of heat, often results in severe engine over-heating.

Protection from both corrosion and scale may be achieved by the use of a cooling system filter of the type shown diagrammatically in Fig. 13. Water or coolant mixture is drawn from the system at a convenient point such as the heater take-off, and enters the filter at port "C," passing through



A Cover bolt — B Cover
C Cover spring — D Oil seals
E Pleated paper cartridge — F Body
G By-pass valve — H Base — J Drain plug

Fig. 12. Typical full-flow filter

cotton fibre media "D" and from there into a bag "B" containing an ion exchange resin together with a mixture of carefully selected corrosion inhibiting chemicals.

The coolant then passes through a paper cup "A" (heavily impregnated with phenolic resin to withstand the effects of prolonged immersion in water), which acts as a screen against the passage of free solid matter and leaves the filter at port "E" in a clean condition and free from the hardness

constituents. Finally, the coolant is returned to the system at any convenient point, usually through a "T" in the heater return hose. A typical installation is shown in Fig. 14, where it will be observed that the by-pass technique has been applied.

A cation exchange resin is used for water softening, its action being to replace the calcium ions in the water with sodium ions, giving rise to sodium carbonate which always remains in solution without forming scale. However, sodium carbonate is alkaline and also electrically conductive, hence the rise in *p*H and conductivity is neutralized by the addition of suitable additives.

Filter performance is best measured under service conditions and a typical result is given below in respect of a filter fitted to a 100 b.h.p. vehicle.

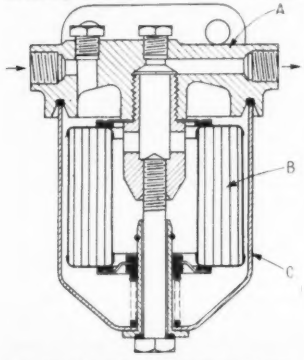
Initial water hardness, parts per million	122
Hardness after 30 min idling p.p.m.	51·5
Mileage to effect a reduction of hardness to 0 p.p.m.	140
Initial *p*H value	8·4
Final *p*H value after 140 miles running	9·0

The alkaline reserve, as indicated by the final *p*H value, demonstrates good corrosion inhibition. The hardness figures speak for themselves. Filters of this type are designed to give a useful life of about six months, allowing for average topping up of the radiator, this figure is approximate because of the wide variation in mineral concentration found in water from different localities.

The filter may be used in conjunction with any anti-freeze mixture without deleterious effects either to the mixture or the engine, in fact, the inhibitors used augment those normally added to anti-freeze fluids.

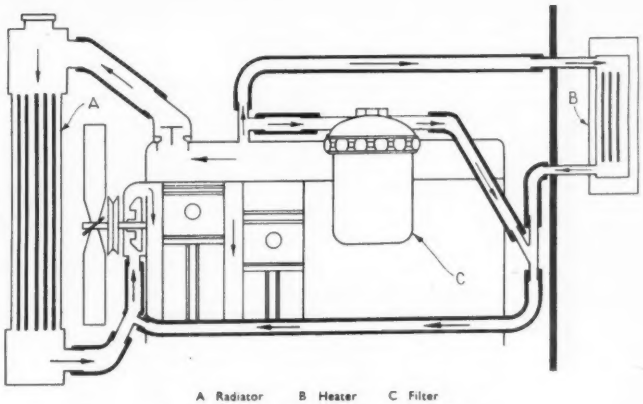
Petrol filtration

Fuel is usually contaminated in three ways, namely, extraneous dust particles, water condensate, rust and manufacturing residuals derived from the fuel tank. To avoid chokes and interruptions in carburation, it is necessary to fit a filter or strainer between the fuel tank and the carburettor. Often the protection is grossly inefficient, particularly when it takes the form of a crude water separator and wire mesh screen. A filter designed to extract efficiently all three basic contaminants is illustrated in Fig. 15. It consists of three major components, a transparent body "A," cartridge "B" and head "C." The zinc alloy cast head is provided with passages directing the flow of petrol to and from the filter cartridge. These passages are terminated by suitable threads to which may be fitted a variety of unions to cater for embodiment in any engine fuel system. The casting is threaded externally to receive the locking ring "D."



A Head B Adsorbent filter paper C Body

Fig. 16. A special filter for diesel fuel



A Radiator B Heater C Filter

Fig. 14. A cooling system with a by-pass filter

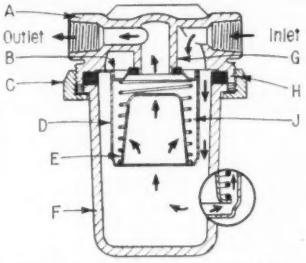


Fig. 15. Arrangement of a petrol filter

The body is a flanged bowl of toughened transparent glass, enabling the user to inspect the accumulation of sediment and water conveniently. The cartridge filter element is replaceable and incorporates a thimble-shaped element "E" constrained by a cylindrical light gauge steel shell. This element is of paper construction, moulded from selected pure cotton linters suitably impregnated with resin to withstand the effects of prolonged immersion in petrol or water. In order to cater for continuous and prolonged water separation, the moulding is finally treated with a silicone.

It will be noted that the space between the cartridge and the bottom of the bowl is relatively great, thus if a heavy concentration of water occurs, it tends to coalesce in this region by reason of the advantageous reduction in velocity and falls to the bottom without coming into contact with the media. The finer globules are rejected by the element which, being silicon treated, allows passage of the petrol phase only.

Rejected water coalesces at the media surface into larger and larger globules which eventually fall by gravity to the bottom of the bowl. Within limits too, the solid contaminants are shaken from the filtering surface in the same way by reason of the engine vibration. The petrol, after seeping through the element, emerges free from water and contaminants at passage "K."

In assembling the filter, the cartridge is located on the head spigot "H" and the gasket "G" slipped over the cartridge and inserted in the counterbore. The bowl is held in position against the gasket and the locking ring screwed up tight. Should the cartridge become plugged with impurities and the user inadvertently fails to change it, the cartridge is designed to act as its own relief valve. When the differential reaches a critical value, the whole element lifts (previously retained in position by spring "L") and enables petrol to by-pass (see inset). Reasonably frequent examination of the bowl, however, should give a good indication of the state of the cartridge. This valve arrangement is looked upon as an expedient only, to avoid the possibility of a complete interruption of flow.

Diesel fuel filtration

The importance of efficient fuel filtration for compression ignition engines cannot be over-emphasized. Not only is it necessary to guard against chokes in nozzle orifices, etc., but also special care must be taken to protect moving parts in the injection pump from abrasive wear. In addition

to dust and water, diesel fuel is often contaminated with a waxy constituent, probably consisting of higher petroleum fractions, which tends to agglomerate on the filtering surface and thereby shorten the effective filter life.

This latter effect makes the choice of media difficult if reasonable life is to be procured. Adsorbent filter paper treated with silicone for water separation has been shown to offer a good compromise. A filter utilizing this media is illustrated in Fig. 16. The element consists of strip paper (resin impregnated), pleated in a lengthwise direction to give a relatively large filtering area.

By means of a suitable sealing medium of the casting resin type, the paper edges are sealed to sheet metal end discs. The filter body is purposely deepened to provide for the reception of solid and liquid contaminant. Access to the element is easily made by removal of the centrebolt when the element may be slipped out and renewed with facility. Filters of this type have proved their worth in service and are particularly efficient in water separation.

Conclusion

It has not been possible in the space available to discuss other important aspects of engine protection such as carburettor air cleaning, crankcase breathing, etc., but it may be possible to discuss them in a future article. However, it is hoped that the views expressed have succeeded in arousing an interest in "protection by filtration." All of the above-mentioned units are manufactured by Messrs. Simmonds Aerocessories Limited, Glamorgan.

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2. W. S. JAMES, B. G. BROWN and B. E. CLARK; "Engine Wear from Abrasives in Intake Air," S.A.E. Paper, October 30-November 1, 1951.
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RECENT PUBLICATIONS

Brief Reviews of Current Technical Books

The Mechanism of the Car

By Arthur W. Judge.

London: CHAPMAN & HALL LTD., 37, Essex St., W.C.2. 1951. 4¼ × 7¼. 446 pp. Price 16s.

The popularity of this book is evidenced by the fact that this is the fifth edition. It is the third in a series of four motor manuals by the same author who is known for his numerous books on automobile and kindred subjects.

A number of alterations have been necessary since the last edition nine years ago and the material has been brought up to date. Perhaps it was the illustrations that most needed changing. We now find illustrations of column gear shifts, Austin A40 gearbox, Armstrong hydraulic shock absorber, the Girling Hydrastatic self-adjusting brake, and a lubrication diagram of the Austin A90 chassis. It would assist the reader who may use this book in the years to come if the dates were given when the vehicles described and illustrated were current models. Possibly these are omitted in books of this type because of reluctance on the part of the publishers, but such information would certainly greatly increase the value of the book to practical men For example, the Humber Pullman is described in detail as a typical example of a modern car chassis, and gear ratios, engine capacity, dimensions, etc., are all given. It is difficult, however, for the reader, unless he be intimately connected with a trade dealing with this type of car, to know if this was the 1950 or 1951 model, or possibly even the 1952 current one.

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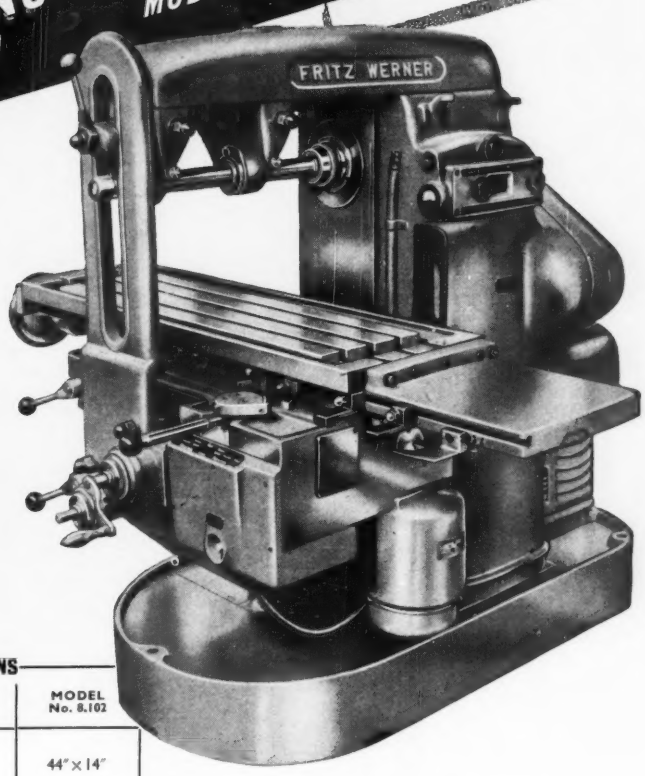

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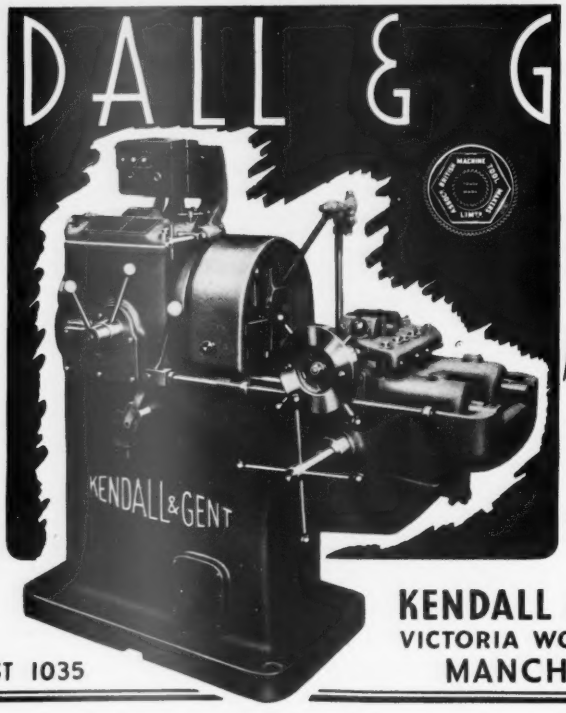

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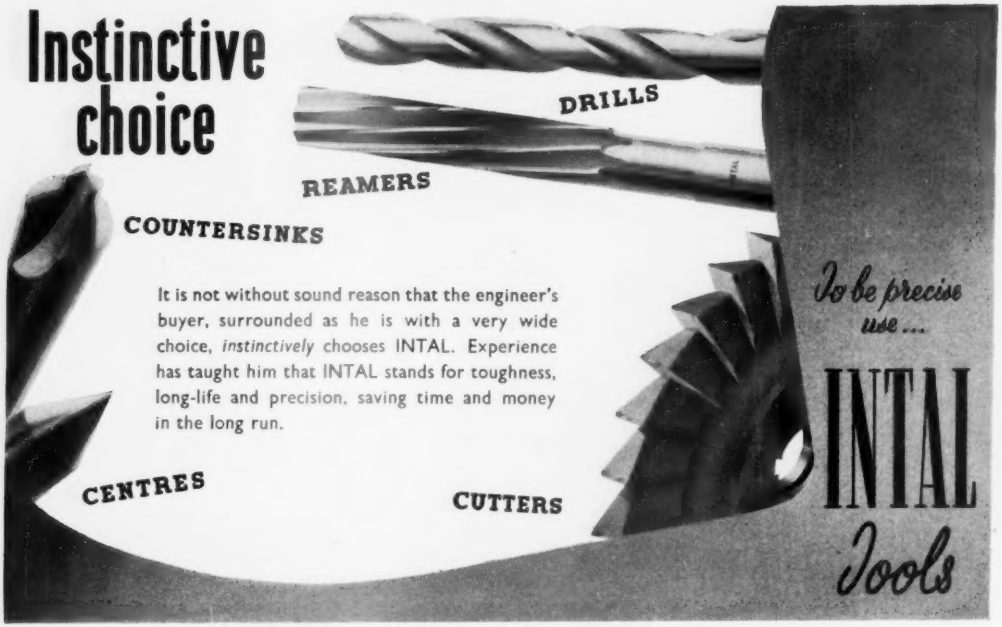

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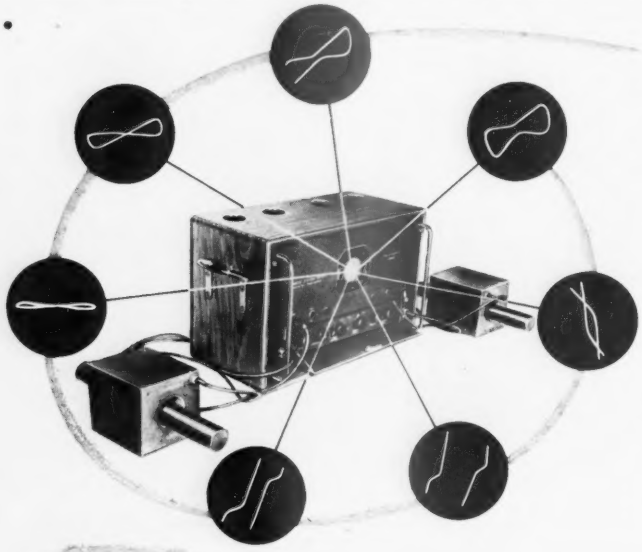

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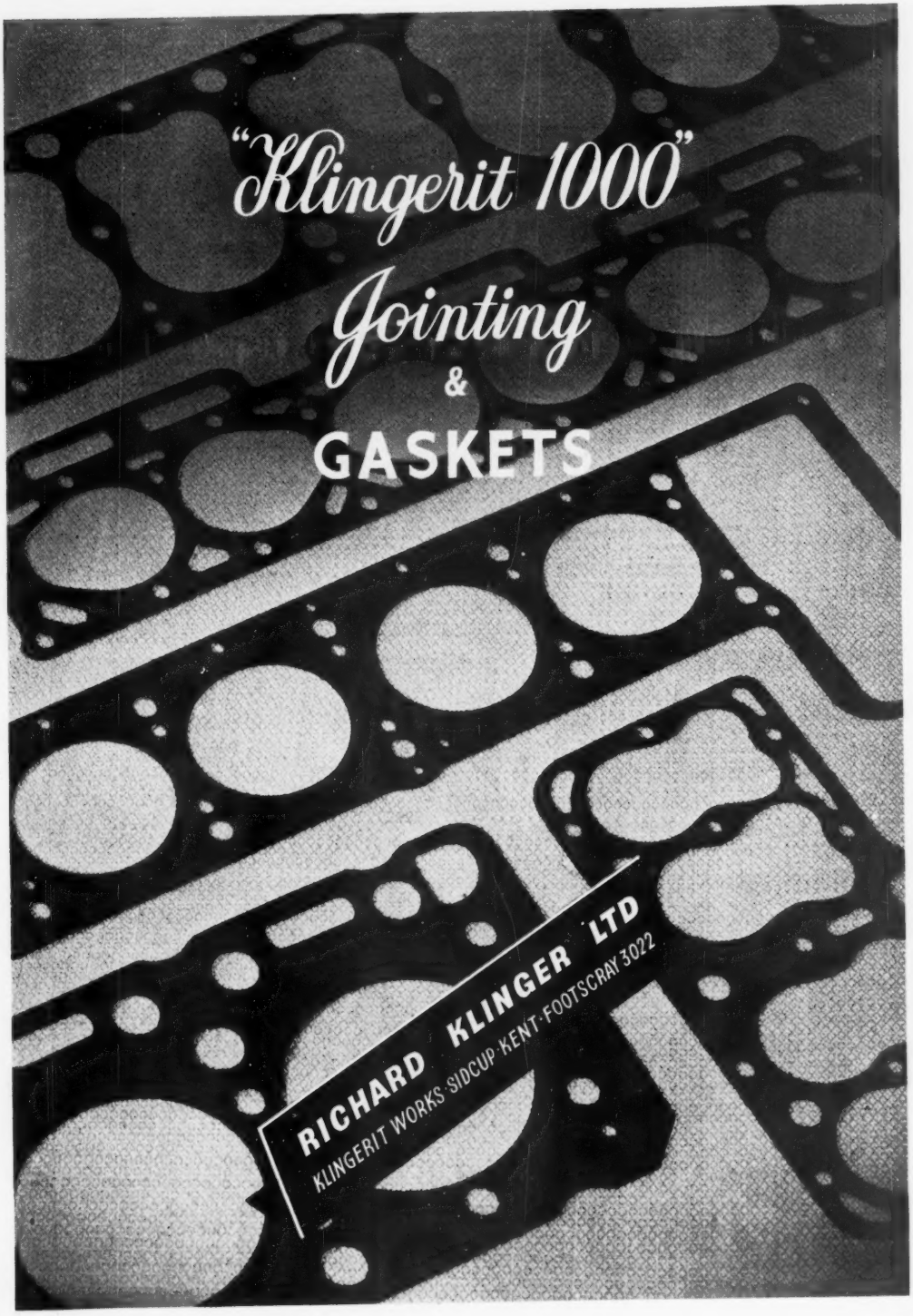
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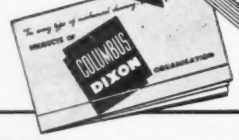

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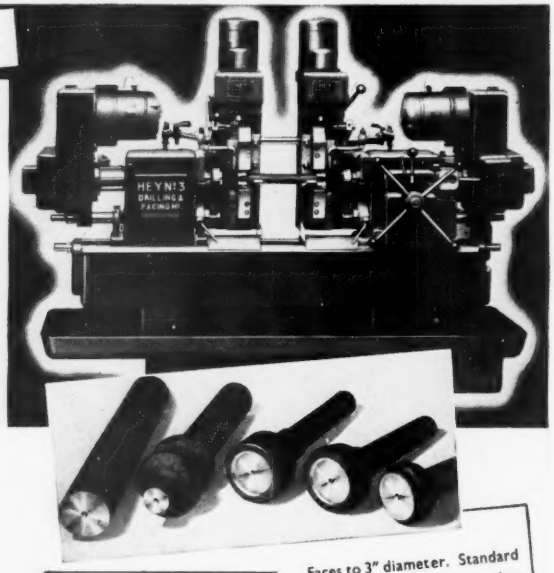

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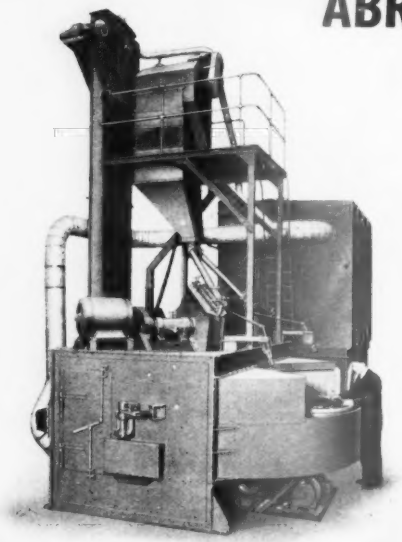

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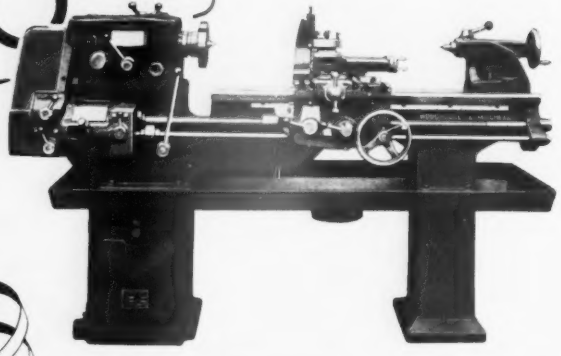

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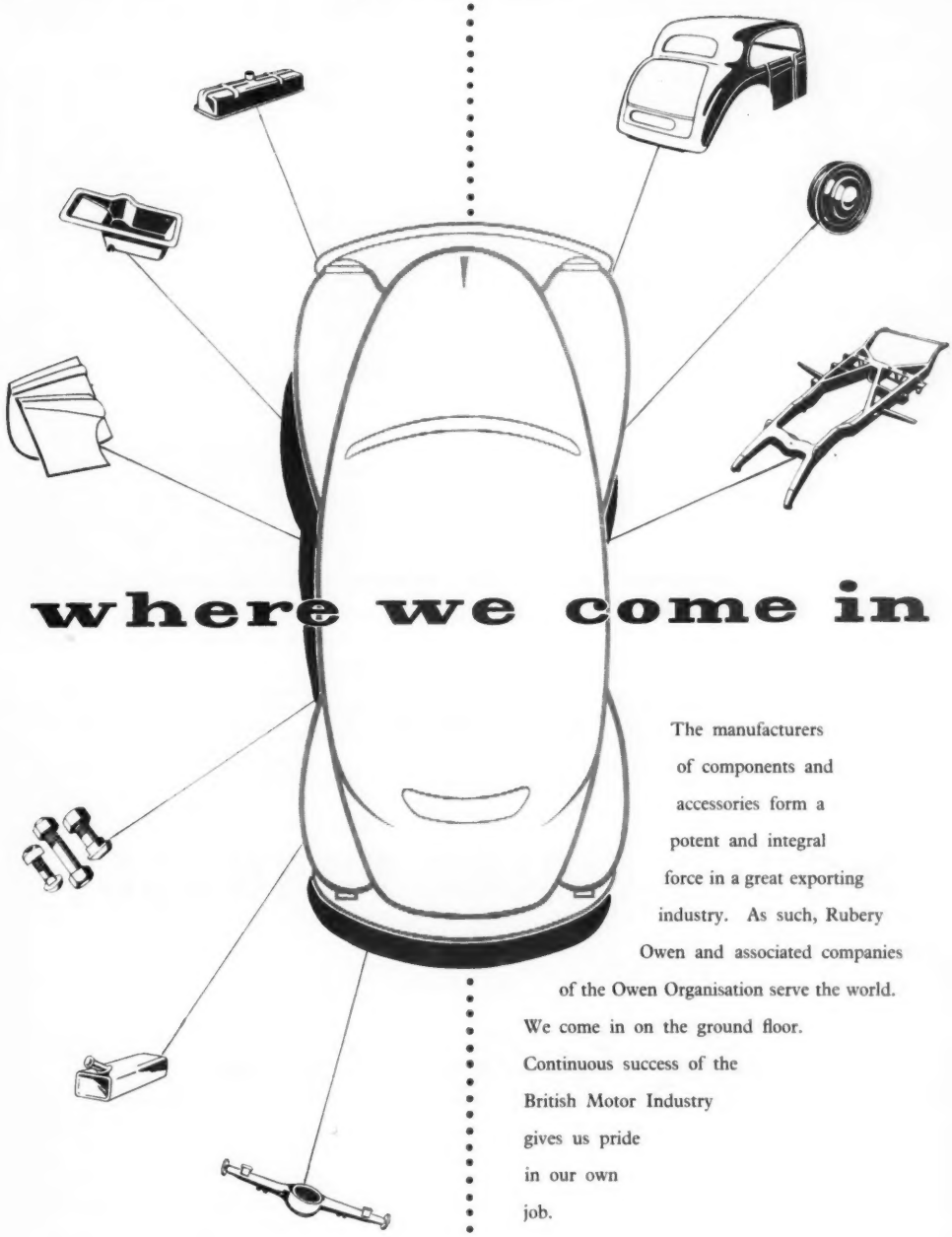

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Of course you would not. The value of a skilled hand cannot be assessed in cash. Better prevent the question arising by installing Udal Guards' There is one for every press.

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AWARDED THE CERTIFICATE OF THE ROYAL INSTITUTE OF PUBLIC HEALTH AND HYGIENE

Safety First

because, only in the BARRYWALD, which is fully patented, will be found the unique safety flame-trap device, which makes contact with the incinerating chamber absolutely impossible when articles are inserted—with the BARRYWALD nobody gets their fingers burnt.

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ready for immediate action in protecting the health of its users by complete destruction of infectious and odorous articles providing a personal service which is at the same time INDISPENSABLE, ECONOMICAL, EFFICIENT and FOOLPROOF.

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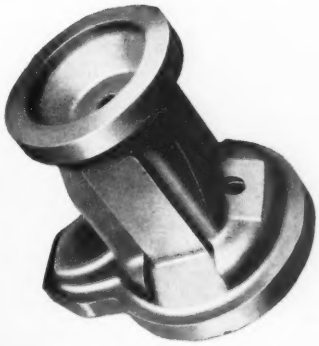
FROM THE "PIG"

TO THE PRODUCT



Lloyds High Duty Irons are under perpetual "quality control"

Although Lloyds castings are produced in large quantities, "quality control" is their constant taskmaster. Every batch of castings has a laboratory pedigree, all raw materials, and every heat, being under constant metallurgical control. Pig iron, scrap, alloys, coke and limestone are tested before reaching the cupola, whilst the charge is analysed every hour to ensure strict adherence to customer's specification. This complete scientific control gives castings a uniform structure, which ensures easy machining, exceptional durability and optimum efficiency. Write for a copy of "Iron Marches On".

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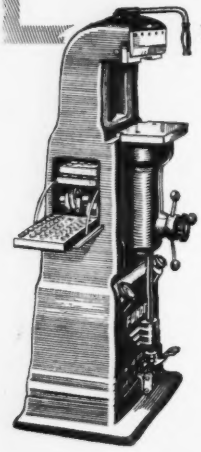
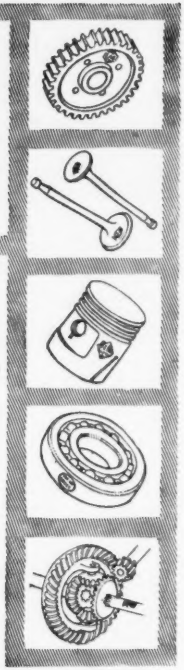
Funditor Marking Machines

FOR THE *SPEEDY* MARKING OF AUTOMOTIVE PARTS



Time is of the essence in marking. That is why so many motor manufacturers have already installed Funditor Marking Machines at the end of each production line. Funditor Marking Machines quickly mark trade-marks, graduations, instructions, part numbers for identification of Spare Parts marks to Government specification, etc. Ask for descriptive literature or send parts for specimen marking.



Funditor Ltd

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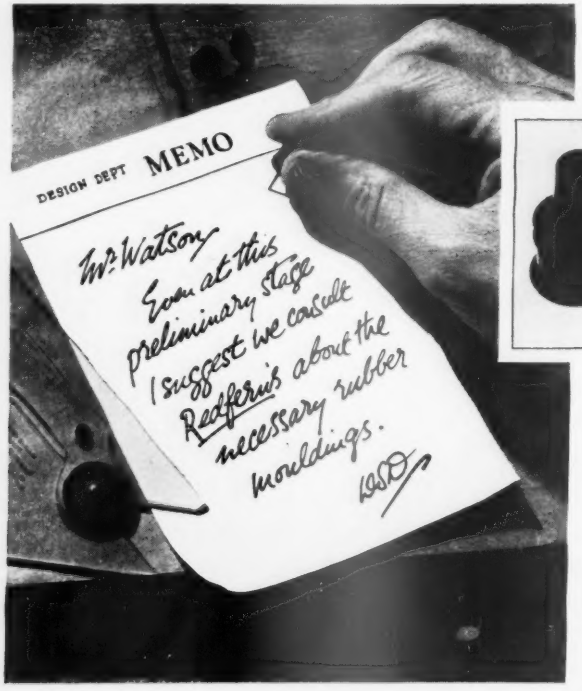
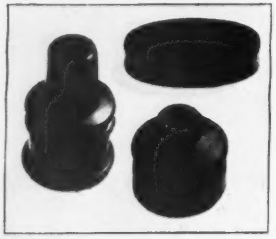
Makers of Hand, Treadle, Pneumatic and Hydraulic Pneumatic Marking Machines, "Sand-Jet" Marking Machines, "Super-saws" for Plastics, Drying Ovens, Electric Heating Elements, etc.


DESIGN DEPT MEMO
Mr. Watson
Even at this preliminary stage I suggest we consult Redfern's about the necessary rubber mouldings.

COMPONENTS



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Consult REDFERN'S at an early stage in your planning

Our rubber technologists – naturally enough—have a highly specialised knowledge of the processing characteristics of rubber. They are always ready to collaborate with designers, at all or any stages of product development. Their experience can help to simplify problems arising before and during production and save both time and money.

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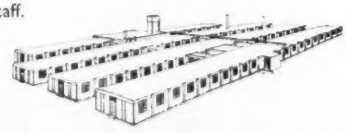
In any event it is worth getting in touch with us so that we can send you our booklet. This will give you full information about our facilities, the instruments we design and make, and the qualifications of our technical staff.



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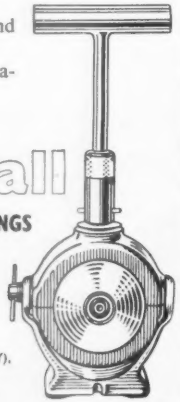

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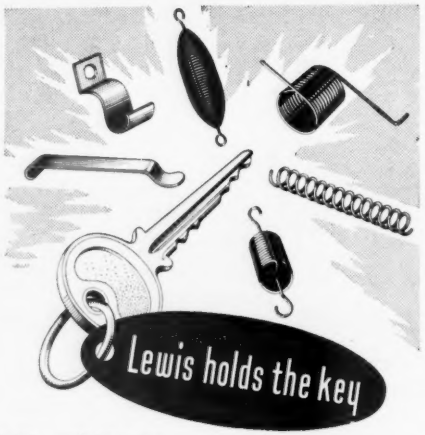

It isn't a magic key or anything like that. It just so happens that we have been called in on many tricky questions over the last thirty years that we now know the answer to most of them. Wouldn't it be a good idea to see us about your new project?
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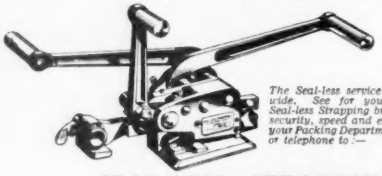

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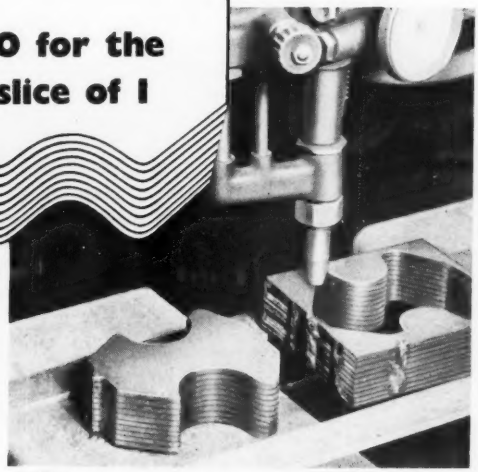

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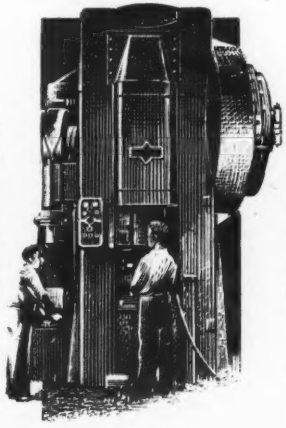

But there is also an abstract form of Craftsmanship: it is the ability to excel in service to one's customers. We believe that the title "Forgemasters" means much more than mere expertness in the shaping of metal, for the forging of friendship—earned by meritorious service—is, in our opinion, a vital ingredient for successful business.

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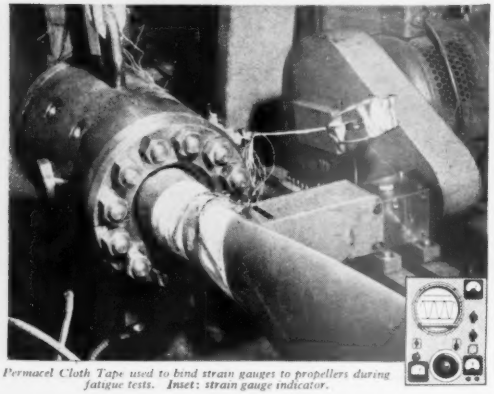
For tenacity De Havilland's choose Permacel masking tapes

made by Johnson and Johnson



Permacel Cloth Tape used to bind strain gauges to propellers during fatigue tests. Inset: strain gauge indicator.

DURING HUNDREDS of hours of continuous vibration, the strain gauges attached to this aircraft propeller must stay precisely in position. That is why De Havilland's have chosen Permacel Cloth Masking Tape to bind them in place, for Permacel will adhere firmly to the smoothest surface. In addition to instant, sure adhesion, Permacel Cloth and Crepe Paper Tapes have two special advantages which lead to greater efficiency in production. They are resilient, and can be used effectively on sharp corners and irregular surfaces. They strip cleanly, leaving no sticky residue. The Paper Tapes, of course, are impervious to oils, acids and the chemicals normally used as solvents in paint and dope.

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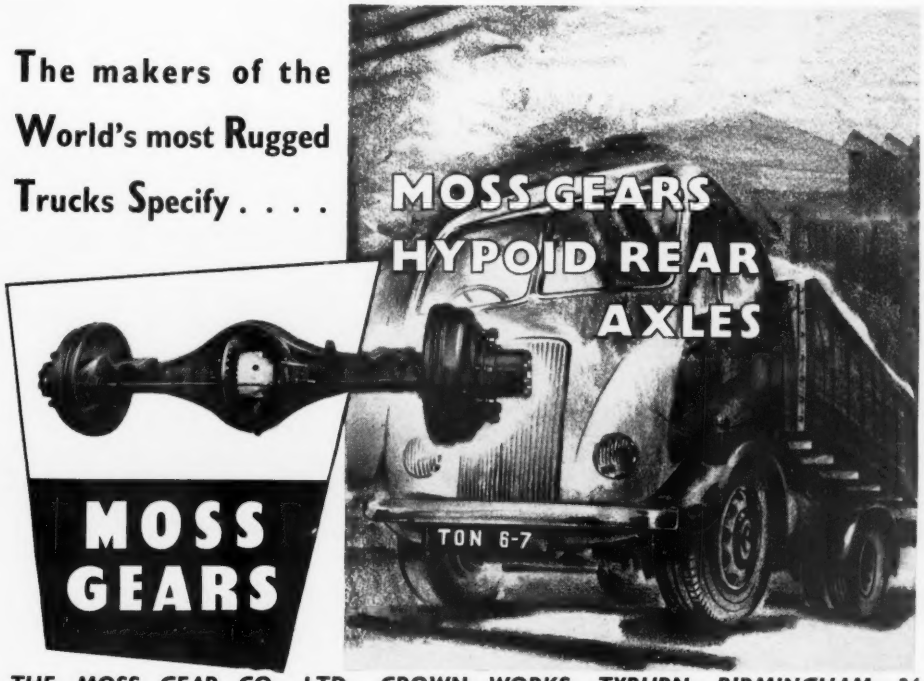

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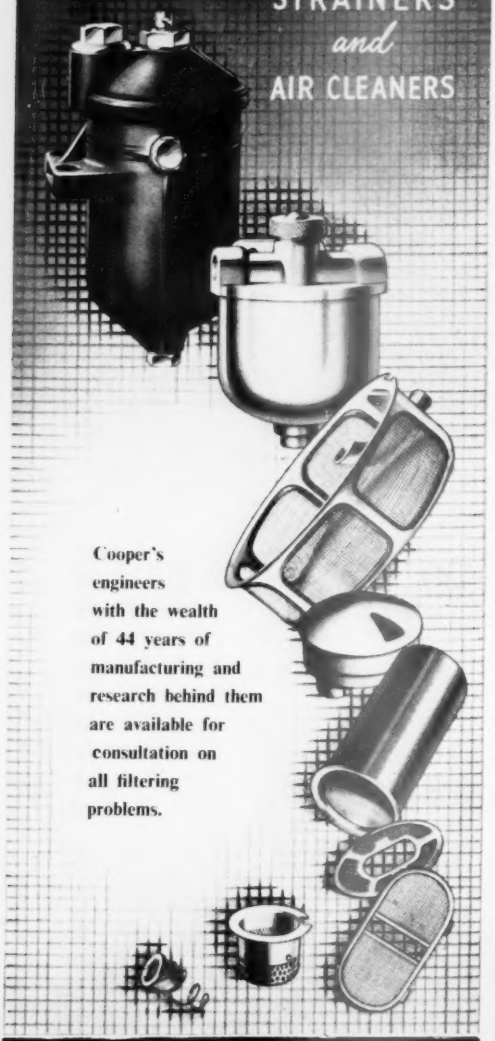

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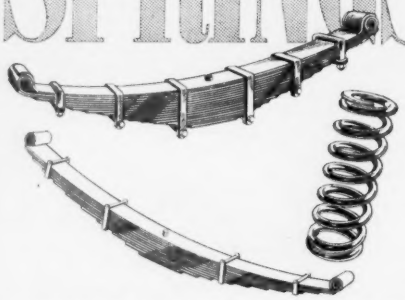

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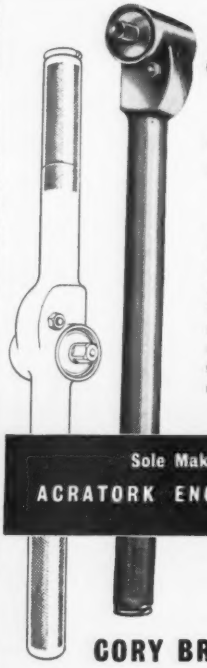

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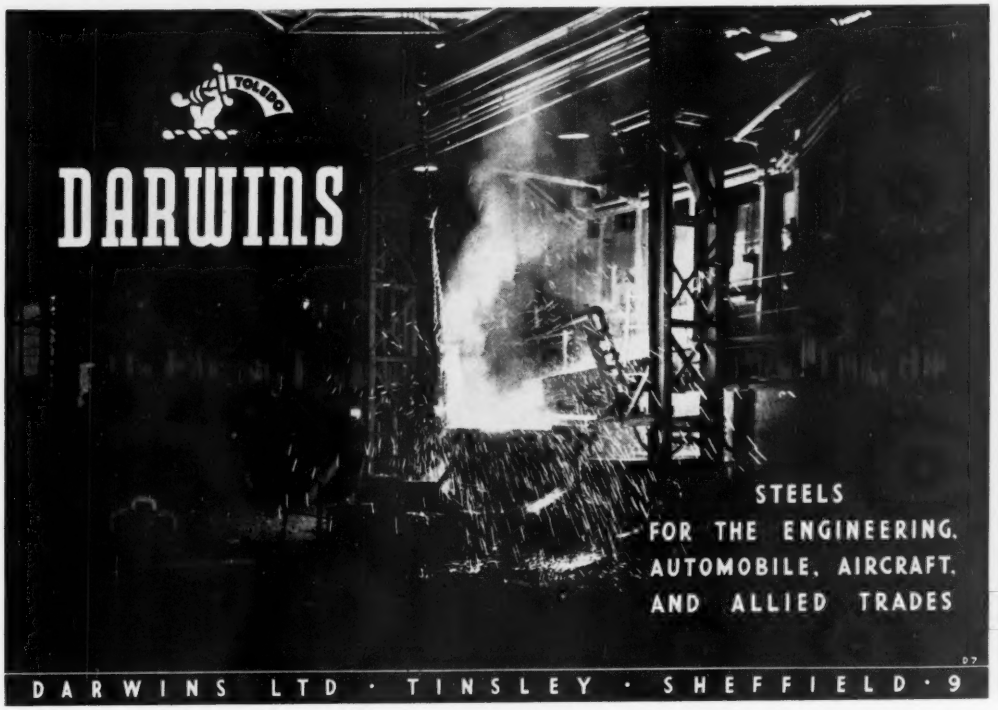

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Acheson Colloids is equipped to do custom disintegrating, dispersing and stabilizing of solids in a wide variety of vehicles.

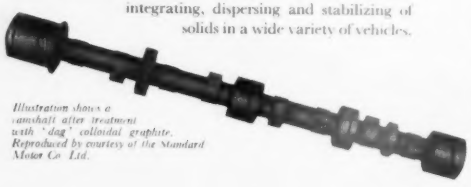

Illustration shows a camshaft after treatment with 'dag' colloidal graphite. Reproduced by courtesy of the Standard Motor Co. Ltd.

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Please send full information concerning the use of 'dag' colloidal graphite in Dry Film Lubrication.

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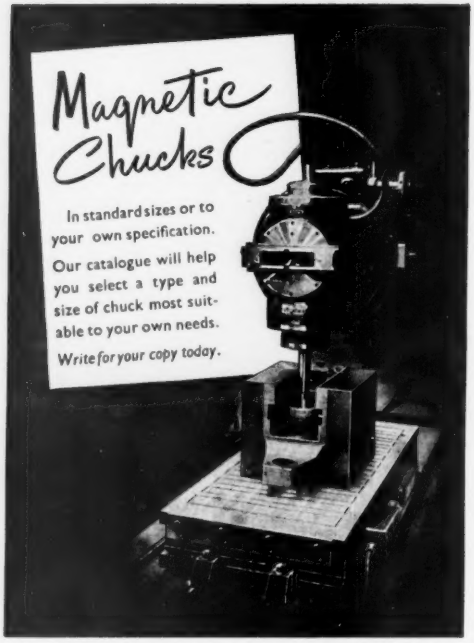
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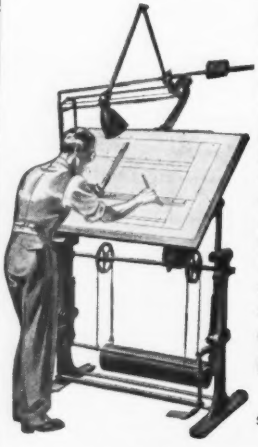

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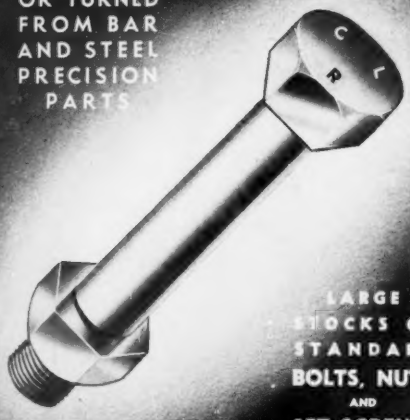

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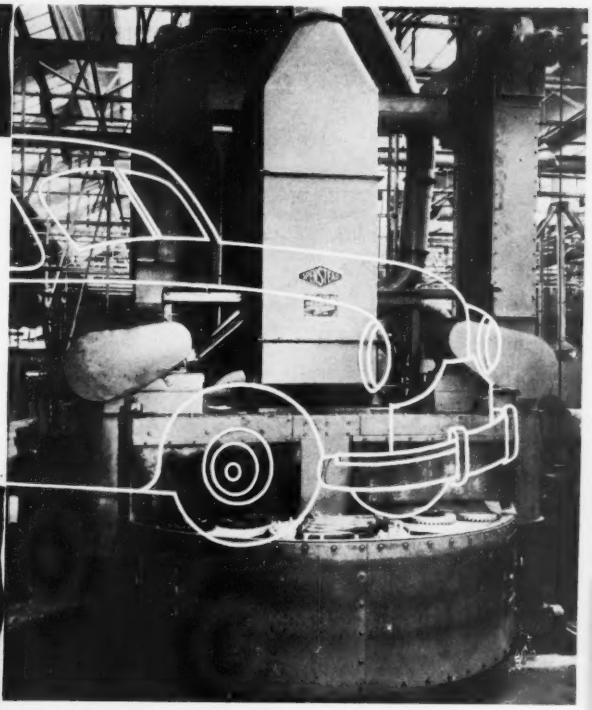

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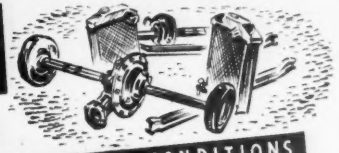
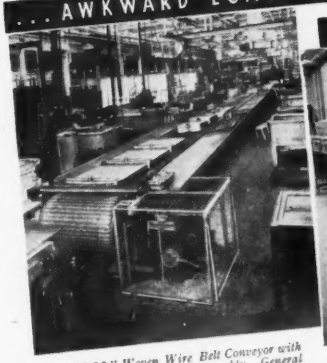


. . . AWKWARD LOADS



"WEDCO" Woven Wire Belt Conveyor with side cables for Radiator Assembly. General view from drive end. Belt fitted with centre guide rolls.
Photo by courtesy of Vauxhall Motors Ltd.

. . . DIVERSE CONDITIONS

Infra-Red Heating Plant using "WEDCO" Woven Wire Conveyor Belts, installed at the Coventry Works of Jaguar Cars Ltd.
Photo by courtesy of Jaguar Cars Ltd., and G.E.C.

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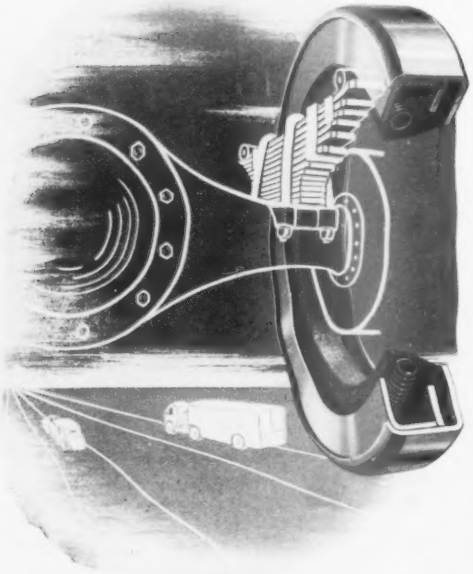

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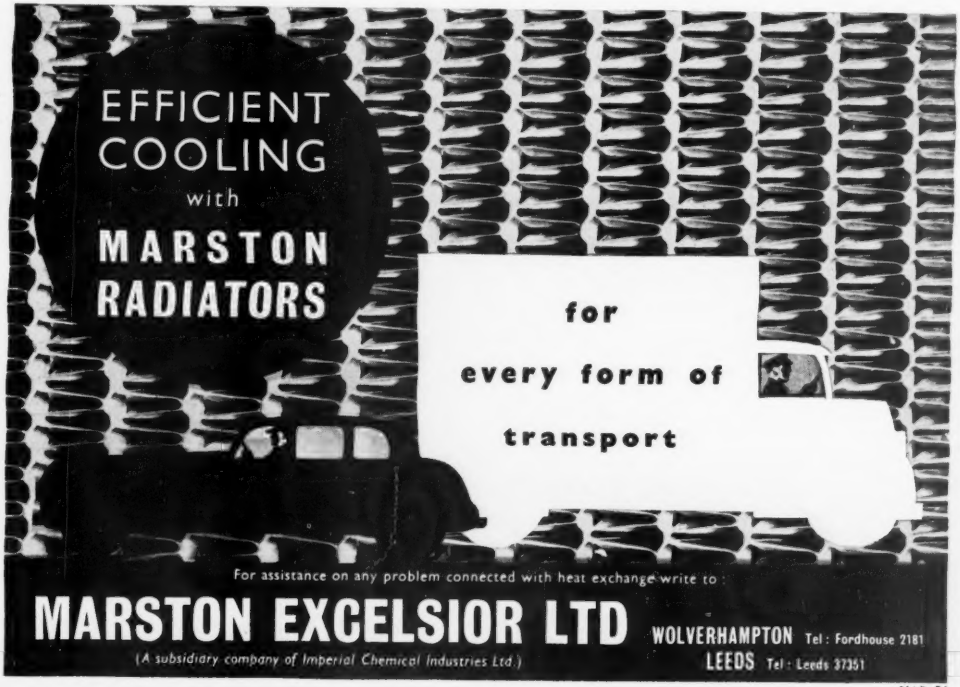
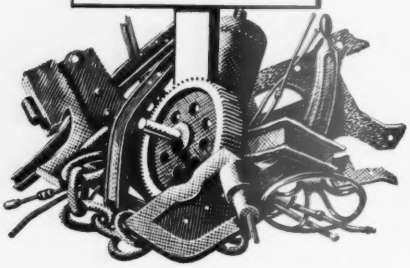


MAR. 94

WHAT EVERY MANAGEMENT SHOULD KNOW ABOUT

scrap



What is scrap?

Obsolete plant and machines, old spares, redundant buildings—anything made from iron and steel for which you have no foreseeable use.

What good is it to me?

No good at all in its present state. But send it back to the steelworks and it can go to make the new steel that you and all steel-users need. Remember—a ton of scrap may make a ton of new steel.

Can't they make steel without scrap?

Yes—but not enough steel. Last year, 58% of our steel was made from scrap. The more scrap we use the more coal, coke and iron ore we save for other important purposes.

What should I do with my scrap?

See your local scrap merchant. He will be glad to help with dismantling and collection. If you have any trouble disposing of iron and steel scrap, write to the British Iron & Steel Federation for the address of your Joint District Scrap Committee.

What shall I get for it?

You will be paid a fair price for your scrap. MORE IMPORTANT—you will be doing yourself and all steel-using firms a great service by helping to increase steel production.

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SPEED THE STEEL

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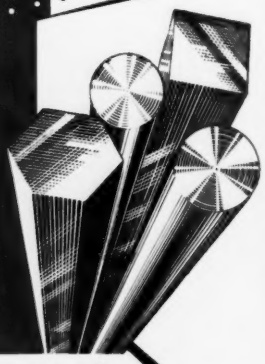

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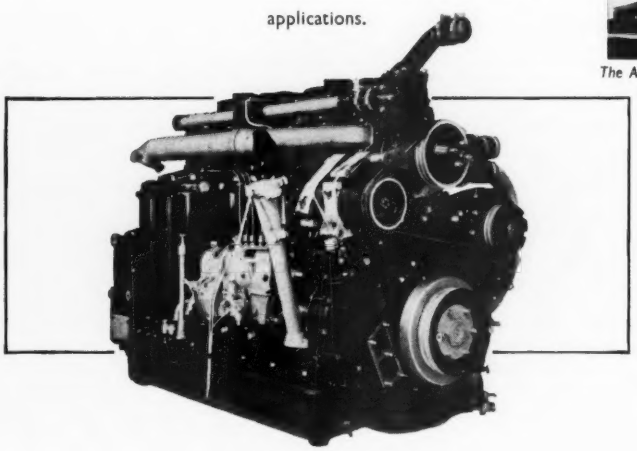

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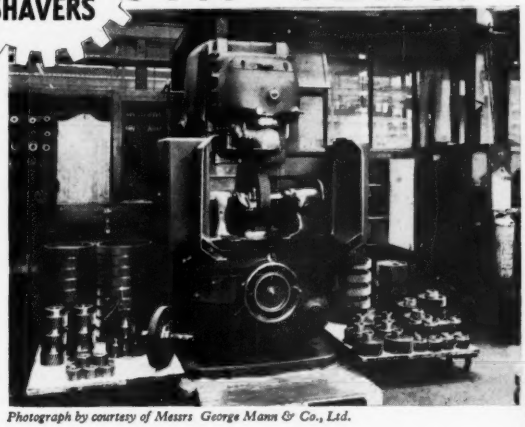

Photograph by courtesy of Messrs George Mann & Co., Ltd.

Of the processes involved in the efficient production of gears, none is quite so vital as that of tooth finishing.

Messrs. George Mann & Co., Ltd., have solved their problem of producing gears to exacting limits of accuracy and uniformly high finish, by installing the Red Ring Gear Shaving Machine illustrated.

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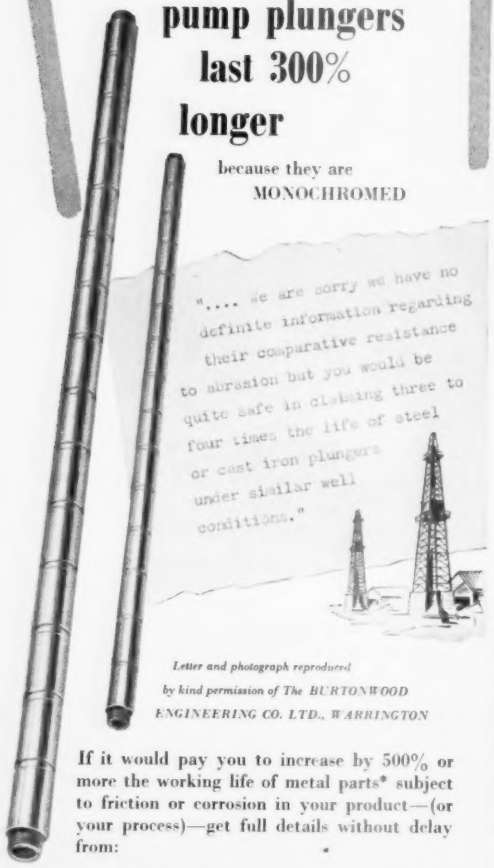
"..... we are sorry we have no definite information regarding their comparative resistance to abrasion but you would be quite safe in claiming three to four times the life of steel or cast iron plungers under similar well conditions."

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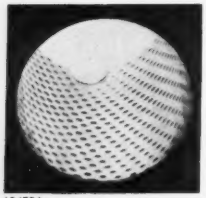

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* *All ferrous and most non-ferrous metals (including many light alloys) can be hard chromium plated by Monochrome.*

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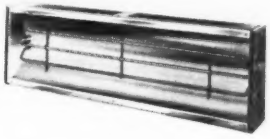

Our Heating Element Department will be glad to discuss your heating problems, and the demonstration rooms at Trafford Park, Manchester and 132/135 Long Acre, London are open for inspection and the actual testing of samples.

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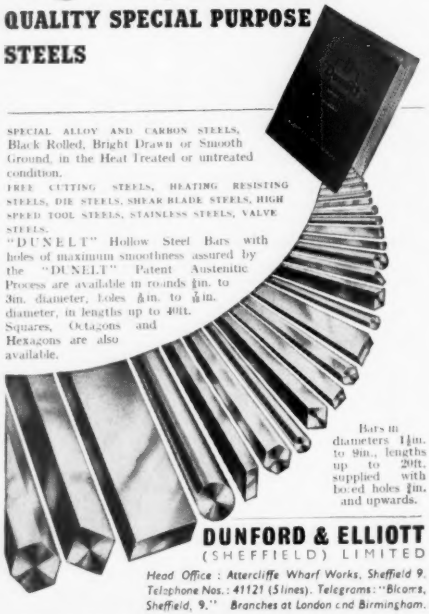

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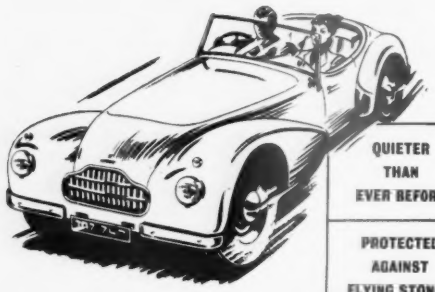

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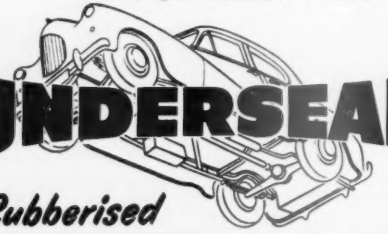

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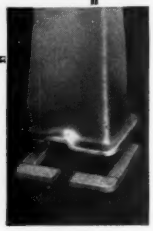

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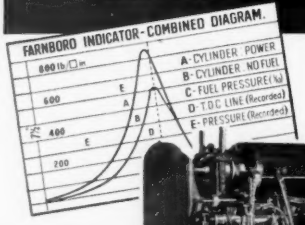

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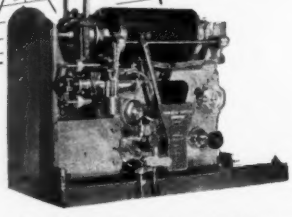

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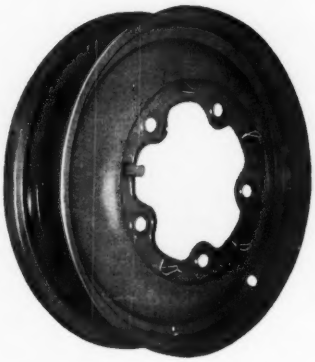

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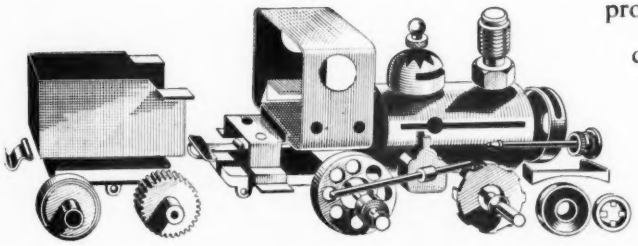

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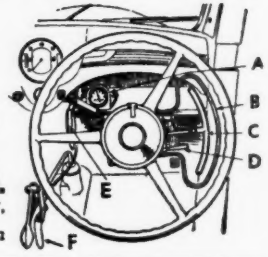

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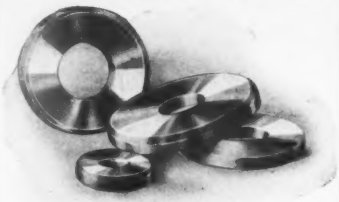

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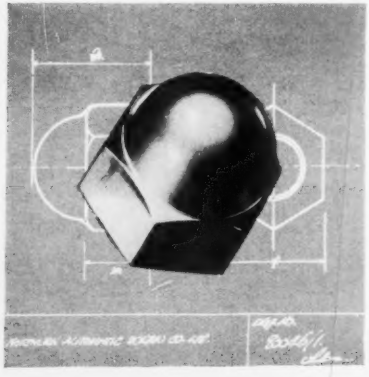

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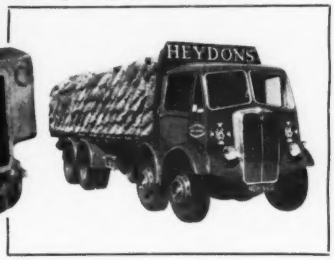

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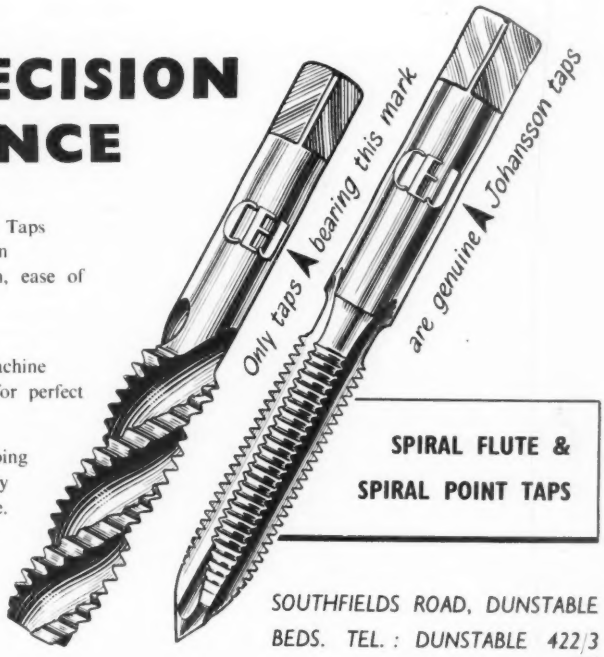

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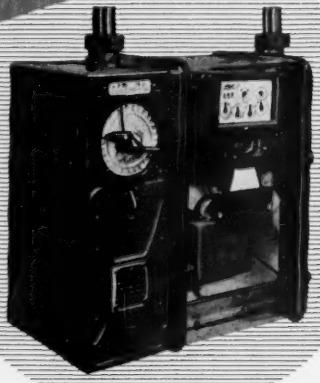

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